

Chapter 7.1 - Pyramid Lake

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Other
Recreation	7.1.3.1						●		●		● 1
Wastewater Treatment/Facilities	7.1.3.2		○			○	○				
Animal Populations	7.1.3.3					●	●		●		
Crude Oil Pipelines	7.1.3.4										● 2
Agricultural Activities	7.1.3.5				○	○					
Mines	7.1.3.6							○	○		
Unauthorized Activity	7.1.3.7										⊙ 3
Traffic Accidents/Spills	7.1.3.8							○	○		○ 3
Geologic Hazards	7.1.3.9								○		● 2
Fires	7.1.3.10										
Land Use Changes	7.1.3.11										

Rating symbols:

- PCS is a highly significant threat to drinking water quality
- PCS is a medium threat to drinking water quality
- ⊙ PCS is a potential threat, but available information is inadequate to rate the threat
- PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes

1. MTBE
2. Oil
3. MTBE and Petroleum Hydrocarbons

Chapter 7.2 - Castaic Lake

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Other
Recreation	7.2.3.1						●		●		● 1
Wastewater Treatment/Facilities	7.2.3.2		○			⊙	●				
Urban Runoff	7.2.3.3								○		
Animal Populations	7.2.3.4					●	● 2		●		
Algal Blooms	7.2.3.5								●	●	
Agricultural Activities	7.2.3.6										
Crude Oil Pipelines	7.2.3.7										
Mines	7.2.3.8										
Traffic Accidents/Spills	7.2.3.9										● 3
Solid/Hazardous Waste Facilities	7.2.3.10										
Geologic Hazards	7.2.3.11										
Fires	7.2.3.12					●			●		
Population/General Urban Area Increase	7.2.3.13										
Land Use Changes	7.2.3.14										

Rating symbols:

- PCS is a highly significant threat to drinking water quality
- PCS is a medium threat to drinking water quality
- ⊙ PCS is a potential threat, but available information is inadequate to rate the threat
- PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes:

1. MTBE
2. From cattle grazing
3. Pump oil spills

Chapter 7.3 - Silverwood Lake

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	MTBE
Recreation	7.3.3.1						●		●		●
Wastewater Treatment/Facilities	7.3.3.2		●			●	●				
Urban Runoff	7.3.3.3								●		
Animal Populations	7.3.3.4					●	●		●		
Algal Blooms	7.3.3.5								●	●	
Agricultural Activities	7.3.3.6				○						
Unauthorized Activity	7.3.3.7										
Geologic Hazards	7.3.3.8								○		
Land Use Changes	7.3.3.9								●		

Rating symbols:

- PCS is a highly significant threat to drinking water quality
- PCS is a medium threat to drinking water quality
- PCS is a potential threat, but available information is inadequate to rate the threat
- PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Chapter 7.4 - Lake Perris

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Other
Recreation	7.4.3.1					●	●		○		● 1
Wastewater Treatment/Facilities	7.4.3.2		○			●	●				
Urban runoff	7.4.3.3										
Animal Populations	7.4.3.4					○	○				
Hypolimnetic Anoxia	7.4.4.1								●	●	
Unauthorized Activity	7.4.3.5										● 2
Land Use Changes	7.4.3.6										

Rating symbols:

- PCS is a highly significant threat to drinking water quality
- PCS is a medium threat to drinking water quality
- PCS is a potential threat, but available information is inadequate to rate the threat
- PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes:

1. MTBE
2. MTBE and petroleum hydrocarbons

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7

Southern California Reservoirs

7.1 PYRAMID LAKE

7.1.1 WATERSHED DESCRIPTION

The Pyramid Lake watershed encompasses a drainage area of approximately 372 square miles. It includes the Piru Creek watershed, the largest non-State Water Project (SWP) inflow to the lake (DWR 1999), and is in both the Angeles and Los Padres national forests (Figure 7-1). The US Department of Agriculture (USDA) Forest Service manages the area and is the key land use decision maker.

Primary land use is recreation, which is associated with both the lake and the Hungry Valley State Vehicular Recreation Area. Land use also includes grazing, mining, and other activities described under Section 7.1.3, Potential Contaminant Sources. The watershed's perimeter is bounded by 3 major geologic faults: the Pine Mountain fault on the south, the Big Pine fault on the northwest, and the San Andreas Fault on the north. Several smaller faults occur locally where rock-type boundaries occur. Soils consist primarily of sediments from the parent rock of the surrounding area. In general, vegetation in the area of the lake is chaparral, with riparian areas occurring along larger creeks and some yellow pine forests occurring in higher elevation areas such as Lockwood Valley.

Because of its large watershed, Pyramid Lake receives a substantial amount of natural inflow. These inflows can be important in determining the water quality of the lake because of the large amounts of sediments and natural constituents contained in the runoff (see Section 7.1.4, Water Quality Summary). The amounts of inflow are shown in Table 7-1.

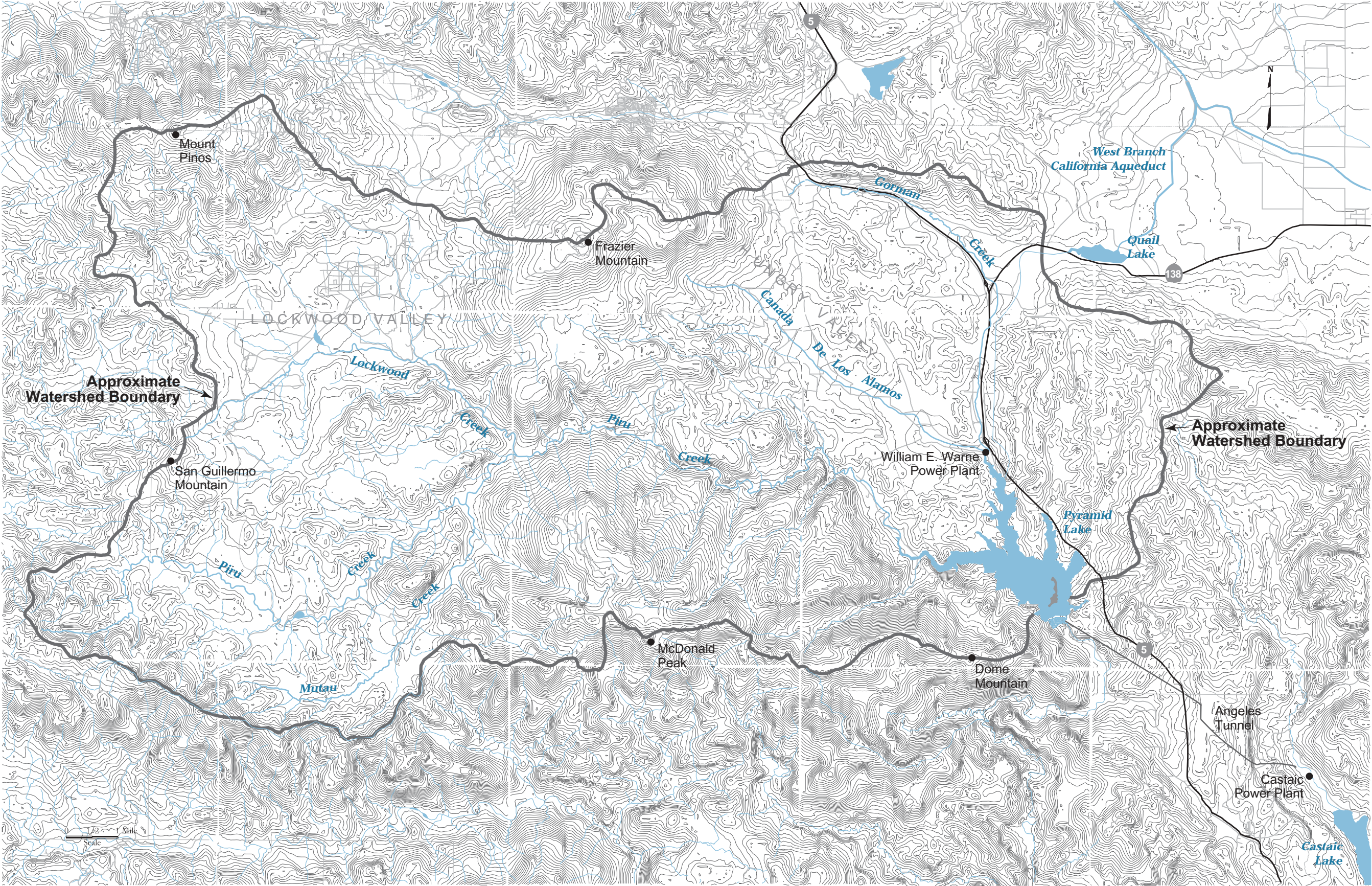
Table 7-1 Total Annual Natural Inflows to Pyramid Lake (acre-feet)

1996	1997	1998	1999
19,352	19,496	133,135	16,493

Source: DWR Division of Operations and Maintenance, SWP Operations Data 1996 to 1999

Piru Creek and its tributaries are the main sources of natural inflow. Piru Creek is the largest creek in the watershed, flowing generally from west to east and entering the lake in the northwest arm. The major tributaries of Piru Creek are Lockwood, Mutau, Frazier, and Snowy creeks. Piru Creek flow is seasonal, depending on the level of rainfall in the wet season. Lockwood Creek receives runoff from seasonal rainfall from the slopes of Mt. Pinos and Mt. San Guillermo. Several ephemeral creeks converge to form Lockwood Creek in Lockwood Valley, including Seymour and Amargosa creeks, Middle Fork, South Fork, and San Guillermo Creek. Hungry Valley is north of the lake and is drained in the lower portion above the lake by the Canada de Los Alamos (a creek), which then flows into Gorman Creek. Gorman Creek flows into Pyramid Lake at the William E. Warne Powerplant. The flow of Gorman Creek is seasonal, mostly underground, and is not noticeable in the dry season.

Figure 7-1 Pyramid Lake Watershed Area



7.1.2 WATER SUPPLY SYSTEM

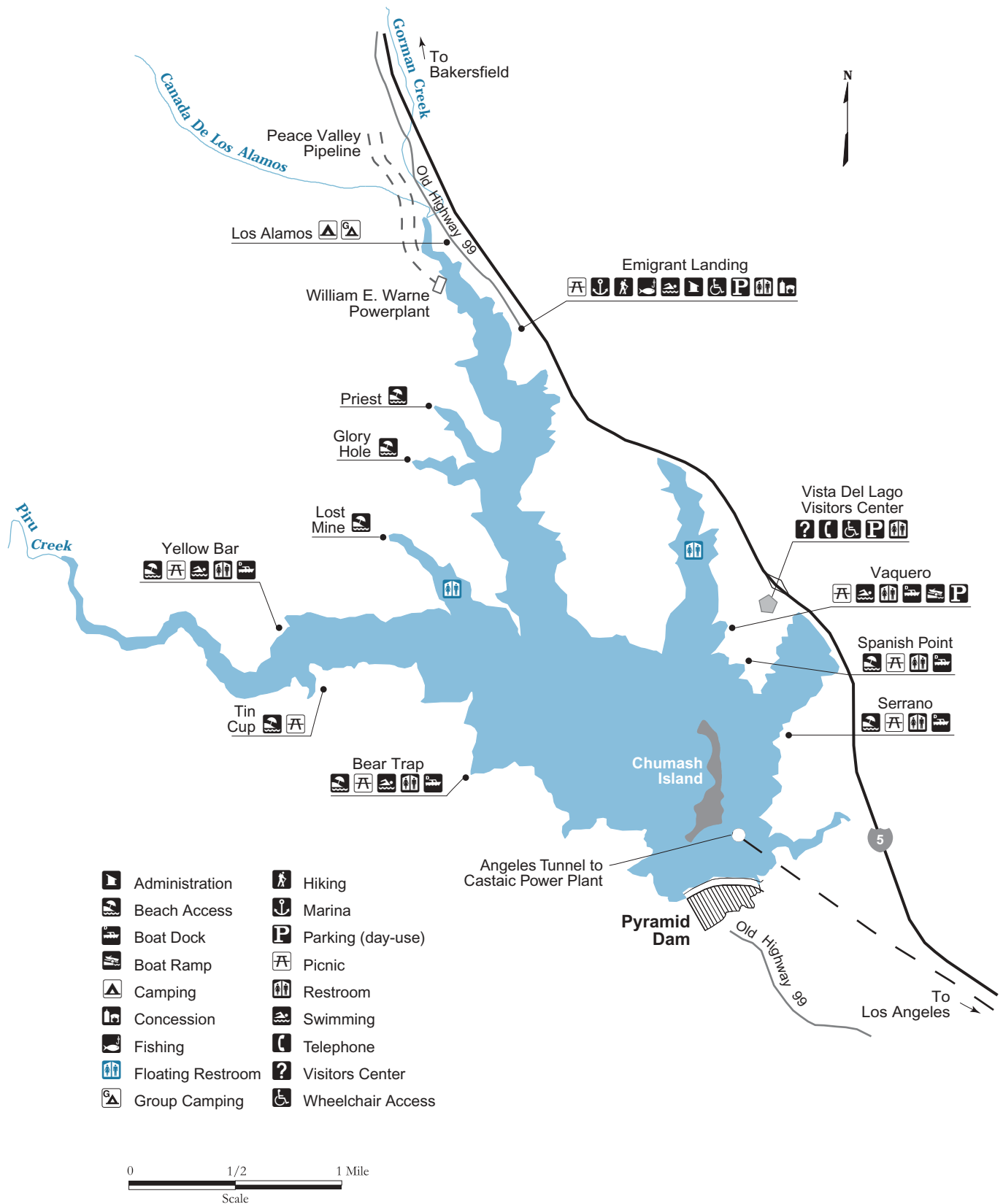
7.1.2.1 Description of Aqueduct/SWP Facilities

Pyramid Lake forms immediately below the Warner Powerplant at the end of the Peace Valley Pipeline at mile 14.07 of the West Branch of the California Aqueduct (Figure 7-2). The lake has an approximate surface area and storage capacity of 1,300 acres and 171,200 acre-feet, respectively. Pyramid Lake dam and facilities were completed in 1973 and provide the following:

- Regulatory storage for the Castaic Powerplant,
- Normal regulatory storage for water deliveries from the SWP West Branch,
- Emergency storage in the event of a shutdown of the SWP to the north,
- Recreational opportunities, and
- Incidental flood protection.

Pyramid Lake water flows to the Castaic Powerplant via the Angeles Tunnel and into Elderberry Forebay. Water is pumped back into Pyramid Lake during off-peak power usage periods so that power can be generated during peak power usage periods.

Figure 7-2 Pyramid Lake



7.1.2.2 Description of Agencies Using SWP Water

The Castaic Lake Water Agency (CLWA) and the Metropolitan Water District of Southern California (MWDSC) use SWP water from the West Branch of the California Aqueduct. Pyramid Lake water is sent to Castaic Lake via the Angeles Tunnel where MWDSC uses the water at the Joseph Jensen Filtration Plant (FP). Pyramid Lake is also the water source for the recreation area and Vista Del Lago Visitor Center.

7.1.3 POTENTIAL CONTAMINANT SOURCES

7.1.3.1 Recreation

The Davis-Dolwig Act of 1961 and State Water Code § 11900 declare that the purposes of SWP facilities shall include recreation and the enhancement of fish and wildlife habitat as well as water storage. In keeping with this mandate, recreation at Pyramid Lake includes many body-contact and nonbody-contact activities. It is a full-service area with boating, personal watercraft riding, water-skiing, windsurfing, swimming, fishing, picnicking, and camping. Recreational amenities are operated under subcontract to the Forest Service by a concessionaire, Pyramid Enterprises, Inc.

The main improvements at Pyramid Lake include 2 campgrounds at Los Alamos, the Vaquero swim beach and launch area, Emigrant Landing day-use picnic area, Forest Service administrative and residential buildings, and 5 boat-in sites (Emigrant Landing is the main boat launching area). All facilities have toilets and comfort stations nearby (USDA 1999). There are 2 floating restrooms; the newer one was installed in 1997.

During the last 2 years, recreational use has significantly declined. The drop in usage is due to lower household economic conditions in the area and construction that required lowering water levels (DWR 1999a). Recreational use is measured in units of "recreation days," which are defined as 1 user visiting the recreation area during part of a 1-day

period (DWR 1999). This information, including the number of boats and cars that entered the recreational area, is presented in Table 7-2.

There have been no new studies or reports on recreation by the Forest Service since 1996 (Wickman 1999).

Several major recreation-related projects have been undertaken at Pyramid Lake since 1996. These include an administrative dock and elevated walkway replacement at Emigrant Landing and a new launch ramp and walkway at Vaquero. The new dock, which accommodates 6 patrol boats and a service barge, has new lights, sewage lines, and water and electric service. There are proposals to upgrade more docks and boat ramps starting in 2000.

Another recreational use is the Hungry Valley State Vehicular Recreation Area, which is operated by California State Parks. The vehicular recreation area is north of Pyramid Lake and occupies about 19,000 acres in the Gorman Creek drainage. About half of this recreation area is drained by the Canada de Los Alamos. Activities in this area can contribute to increased sedimentation and erosion that may contribute sediments flushed into Pyramid Lake via the Canada de Los Alamos and Gorman Creek (Keene pers. comm. 2000). This is a potential concern because there have been ongoing erosion problems in the Gorman Creek channel (Marks pers. comm. 1996). Motor vehicle-related contamination from fuels, oil, and some metals could also occur.

Erosion in campgrounds along creeks, especially along Piru Creek, is another potential source of sediment inflow to the lake.

Personal watercraft is used frequently and is a potential source of petroleum-related contaminants, including MTBE.

7.1.3.2 Wastewater Treatment/Facilities

There are no known wastewater treatment plants or effluent discharges at Pyramid Lake or in the watershed. There is no storage or disposal to land of wastewater effluents. There are pit toilets in the picnic areas and campgrounds.

Table 7-2 Recreational Use at Pyramid Lake

	1996	1997	1998	1999
Recreation days	300,000	315,000	182,200	207,000
Boats	NA	22,333	18,354	17,581
Cars	NA	21,385	24,301	22,979

NA = not available

Storage, Transport, and Disposal

Emigrant Landing has 6 flush toilets. There are restrooms with vault toilets at all boat-in sites. The swim beach area has 2 toilets and shower facilities (USDA 1999). All flush toilets go to concrete holding tanks under each area. As part of the concessionaire operations, all holding tanks, vault toilets, and septic systems are regularly pumped out by truck and disposed of outside the watershed (Roberts pers. comm. 2000). The Los Alamos camping area about 3 miles north of the lake has 5 vault-toilet areas and a septic leach field. There were no reports of accidents or spills (Roberts pers. comm. 2000).

Septic Systems

There are septic systems associated with the administrative/residential area north of the lake off Interstate 5. Septic systems in the recreation areas are pumped out as described above. There is also a septic system and leach field about a quarter mile north of the Warne Powerplant.

7.1.3.3 Animal Populations

Historically, there has been extensive grazing of cattle and sheep in the watershed. Although new information on grazing allotments was not available from the Forest Service, it is known that grazing still occurs and, therefore, has the potential to contribute pathogens and sediment via erosion to creeks and streams entering the lake. There is also a substantial but unknown wild animal population in the watershed that is also a potential source of pathogens in creeks and streams entering the lake.

7.1.3.4 Crude Oil Pipelines

Several crude oil transmission pipelines pass through the Pyramid Lake watershed carrying oil from the Kettleman Hills to refineries in Los Angeles County. There were 3 pipelines in the vicinity of Pyramid Lake, but 1 line (known as Line 1) has been shut down and the oil removed. The other lines are owned and operated by Pacific Pipeline.

One of the lines (known as Line #63) enters the watershed northeast of Pyramid Lake, parallels I-5 near Vista Del Lago, and runs about one-quarter mile above the lake at Gorman Creek, and continues south down to the Emigrant Landing area and on to Castaic Lake. This line, and this area in particular, has the greatest potential to impact water quality in Pyramid Lake (Kellogg pers. comm. 2000). Line #63 also has a pump station in Hungry Valley, north of Pyramid Lake in the Gorman Creek drainage.

This whole area can be prone to pipeline ruptures caused by seismic activity, which can disrupt transmission and damage roads, etc. There have been no releases or breaks in the lines during 1996 through

1999. The last line break occurred during the 1994 Northridge earthquake in Posey Canyon, approximately three-quarters of a mile from the Posey Creek arm of the lake. Reportedly, no oil made it to the lake. (Kellogg pers. comm. 2000).

7.1.3.5 Agricultural Activities

Agricultural Crop Land Use and Pesticide/Herbicide Use

There is some limited agricultural use in the form of pasture crops such as alfalfa to support the grazing activities. No information was available on pesticide use, but commonly used pesticides on alfalfa include chlorpyrifos and other organophosphate pesticides and herbicides.

7.1.3.6 Mines

There are 12 mines in the watershed, many of which are supposedly active gold mines (DWR 1996). These mines are not known to discharge to surface waters, and no evidence or indication of contamination has been reported or found.

7.1.3.7 Unauthorized Activity

Leaking Underground Storage Tanks

There was 1 leaking underground storage tank reported in 1992 that was removed, and remediation was begun (DWR 1996). This site is still being monitored quarterly, but it is not known if there are any effects on lake water quality. No new leaking tanks were reported, and there were no reports of illegal dumping.

7.1.3.8 Traffic Accidents/Spills

The proximity of I-5 and Highway 138 to the watershed and immediate lake area indicates vulnerability from spills along these routes. On 3 March 1998, a tanker truck spilled about 2,500 gallons of diesel fuel on I-5 with much of the spilled fuel draining into Gorman Creek. By chance a hazardous spill crew was nearby and able to contain the spill locally (MWDSC 2000). The Project Operations Center (POC) reported no other incidents, spills, or accidents for Pyramid Lake.

There are 3 airplane landing strips in Lockwood Valley that could be potential sources of petroleum-related contaminants, but there was no information on specific activities.

7.1.3.9 Geologic Hazards

The 3 major faults and several smaller faults in the watershed make the area susceptible to pipeline ruptures (such as crude oil) and other facility damage caused by seismic activity (see Section 7.1.3.4, Crude Oil Pipelines).

7.1.3.10 Fires

There were no fires of significance reported during this survey period.

7.1.3.11 Land Use Changes

The only known land use changes associated with construction were recreation-related improvement projects described in Section 7.1.3.1, Recreation. There are no other known major land use changes in the watershed.

7.1.4 WATER QUALITY SUMMARY**7.1.4.1 Watershed**

Water quality data for Pyramid Lake for the 1996 through 1999 period are presented in Table 7-3.

Parameters of interest in the Pyramid Lake watershed, including MTBE, are discussed later in this section. All parameters were below drinking water maximum contaminant levels (MCLs) or applicable Article 19 objectives for this period, except for hardness in May 1998 (see discussion under Total Dissolved Solids). Assessing water quality in Pyramid Lake is complicated by the recirculation of water from Elderberry Forebay and because most management agencies focus water quality investigation on Castaic Lake, the point of delivery of SWP water.

Table 7-3 Pyramid Lake at Tunnel Inlet, Feb 1996 through Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	29	26	22	45	23-39	1	16/16
Chloride	44	43	36	58	36-53	1	16/16
Total Dissolved Solids	266	257	228	339	233-311	1	17/17
Hardness (as CaCO ₃)	128	118	100	183	106-163	1	16/16
Conductivity (µS/cm)	455	435	401	552	414-524	1	16/16
Magnesium	13	12	11	17	12-16	1	16/16
Sulfate	67	66	45	107	47-92	1	16/16
Turbidity (NTU)	4	2	1	21	1-8	1	14/14
Minor Elements							
Aluminum	0.01	0.01	<0.01	0.02	<0.01-0.02	0.01	5/15
Arsenic	0.002	0.002	0.002	0.003	0.002-0.002	0.001	15/15
Boron	0.3	0.3	0.2	0.4	0.2-0.4	0.1	16/16
Chromium	0.005	0.005	<0.005	0.007	<0.005-0.006	0.005	4/15
Copper	0.003	0.003	0.002	0.005	0.002-0.005	0.001	10/15
Iron	0.006	0.005	<0.005	0.018	<0.005-0.008	0.005	3/15
Manganese			<0.005	0.020		0.005	2/15
Zinc			<0.005	0.008		0.005	1/15
Nutrients							
Total Kjeldahl Nitrogen (as N)	0.4	0.3	0.1	2.1	0.2-0.6	0.1	26/26
Nitrate (as NO ₃)	1.8	1.8	0.2	2.5	1.3-2.5	0.1	16/16
Nitrate+Nitrite (as N)	0.46	0.45	0.15	0.71	0.31-0.61	0.01	46/46
Total Phosphorus	0.07	0.07	0.01	0.27	0.04-0.08	0.01	46/46
Orthophosphate	0.05	0.05	0.01	0.07	0.03-0.06	0.01	46/46
Misc.							
Bromide	0.12	0.11	0.11	0.13	0.11-0.13	0.01	3/3
pH (pH unit)	7.9	8.0	7.2	9.2	7.4-8.2	0.1	16/16

Source: DWR O&M Division database, May 2000

Notes: Turbidity and bromide data from Aug 1996 to Nov 1999 and Feb 1999 to Nov 1999, respectively

Statistics include values less than detection limit, if applicable

In the reservoir water quality sections, comparisons are made between contaminant concentrations in SWP source water and MCLs for finished drinking water. Although MCL is usually applied to finished water, it is useful as a conservative indicator of contaminants that are of concern to utilities and require removal during the treatment process to meet finished water standards. The comparison also serves to focus on the particular PCS associated with the contaminant of concern and then develop appropriate recommendations for actions. It follows that if source water concentrations were below MCLs, then these contaminants were not likely to be of concern to finished water supplies.

Water quality in Pyramid Lake is strongly affected by runoff from its large watershed, in particular the inflows from Piru Creek. The largest non-SWP inflow source to the lake, Piru Creek is elevated in total dissolved solids (TDS) from marine sediments in the watershed and contributes to the lake's salinity (DWR 1999). Natural inflows were 19,352 acre-feet in 1996 and 19,496 acre-feet in 1997, amounting to about 5% of total annual inflows. However, this inflow comprised from 10% to 14% of total lake inflows during December, January, and February of both years. In 1998, natural inflows totaled 133,135 acre-feet, or about 52% of the total lake inflow from all sources and about 6 times the normal natural inflow to the lake. Piru Creek was the only source of inflow (that is, no SWP inflow) to the lake

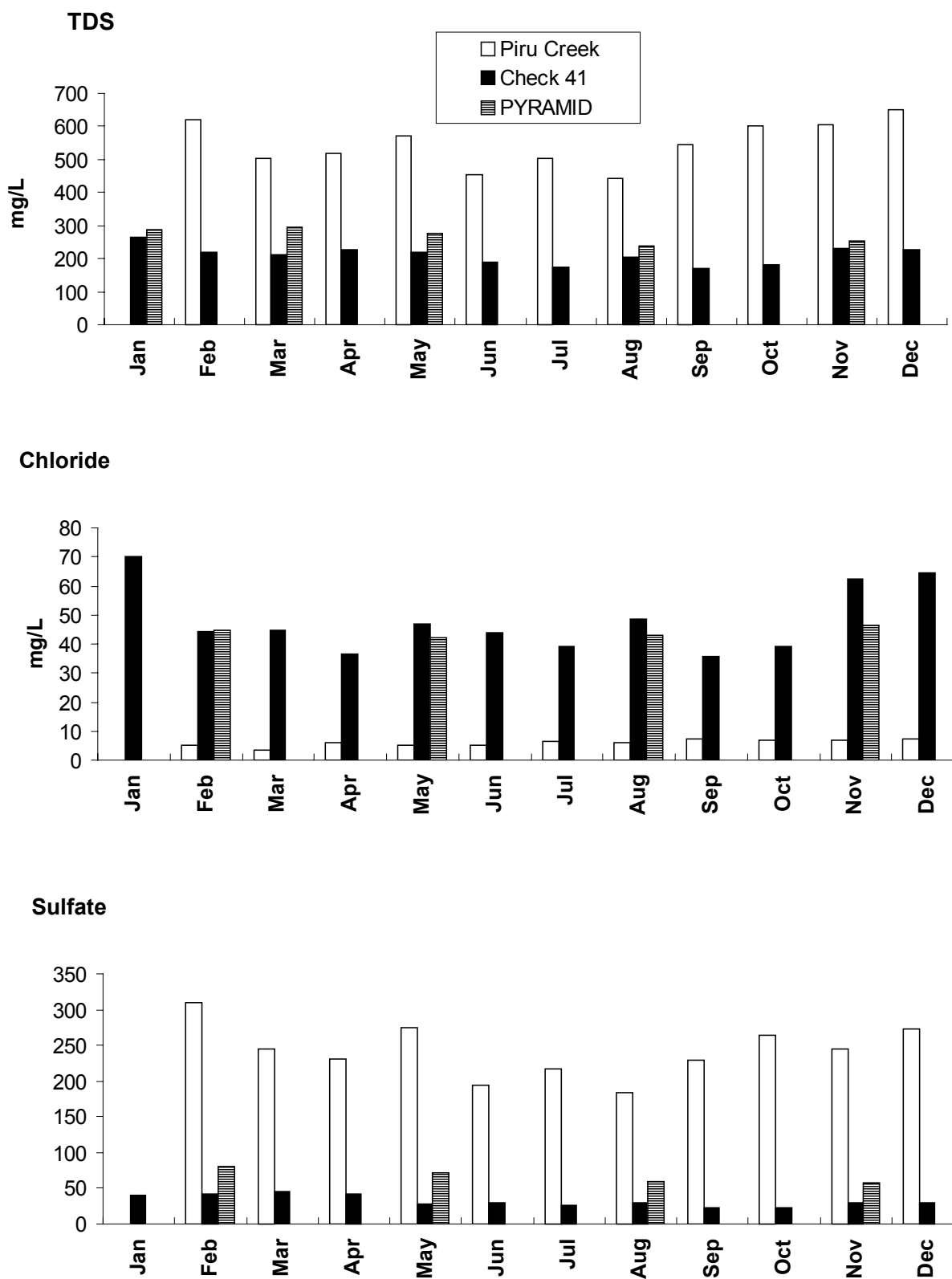
from March to May 1998 and January to February 1999 (DWR 2000).

Minor elements (for example, trace elements) that were detected in 1 or more samples but at low levels included aluminum, arsenic, boron, chromium, copper, iron, manganese, and zinc (Table 7-3). Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations as the detection limit; however, statistics were not calculated for parameters with 2 or fewer detections.

Bromide levels have only been monitored since 1999 and ranged from 0.11 to 0.13 mg/L, which is similar to the other Southern California reservoirs and SWP inflows.

Total Dissolved Solids

Because of its high TDS levels, Piru Creek has a measurable influence on the salinity of Pyramid Lake, especially during wet years (DWR 1999). Mineralogy analyses have indicated Piru Creek as the clear source of the TDS and sulfate, in addition to SWP inflows. TDS levels in Piru Creek ranged from 423 to 763 mg/L and averaged 554 mg/L (1994 to 1995 data), compared to 266 mg/L in Pyramid Lake. SWP inflows ranged from 114 to 266 mg/L and averaged 198 mg/L (Check 41) during 1996 to 1999. Check 41 is above the bifurcation to the East and West Branches of the California Aqueduct (Figure 7-3).

Figure 7-3 Total Dissolved Solids in Pyramid Lake and Inflows, 1996 to 1999

There were high TDS levels during early 1996 caused by unusually high inflows from Piru Creek in 1995. Inflows during 1995 totaled 105,454 acre-feet or 35% of lake inflow from all sources. TDS, sulfate, and hardness declined steadily during 1996 because of large SWP inflows but remained constant during 1997. TDS levels ranged from 228 to 339 mg/L and averaged 266 mg/L. Hardness levels ranged from 100 to 183 mg/L and averaged 127.5 mg/L.

The high TDS levels are due primarily to the high sulfate/bicarbonate composition of the Piru Creek watershed. Average sulfate concentrations in Piru Creek are 8 times higher than SWP water, yet average chloride concentrations are 9 times lower (Figure 7-4). Hardness (as calcium/magnesium) is also high. In May 1998, the hardness was 183 mg/L, which exceeded the Article 19 objective of 180 mg/L. This was due to the high percentage of inflow provided by Piru Creek during the 1998 wet season. In high inflow years such as 1998, sulfate and hardness typically increase by May and decrease in summer, depending on the volume of SWP inflows. Similar effects and trends were observed in Castaic Lake.

Nutrients

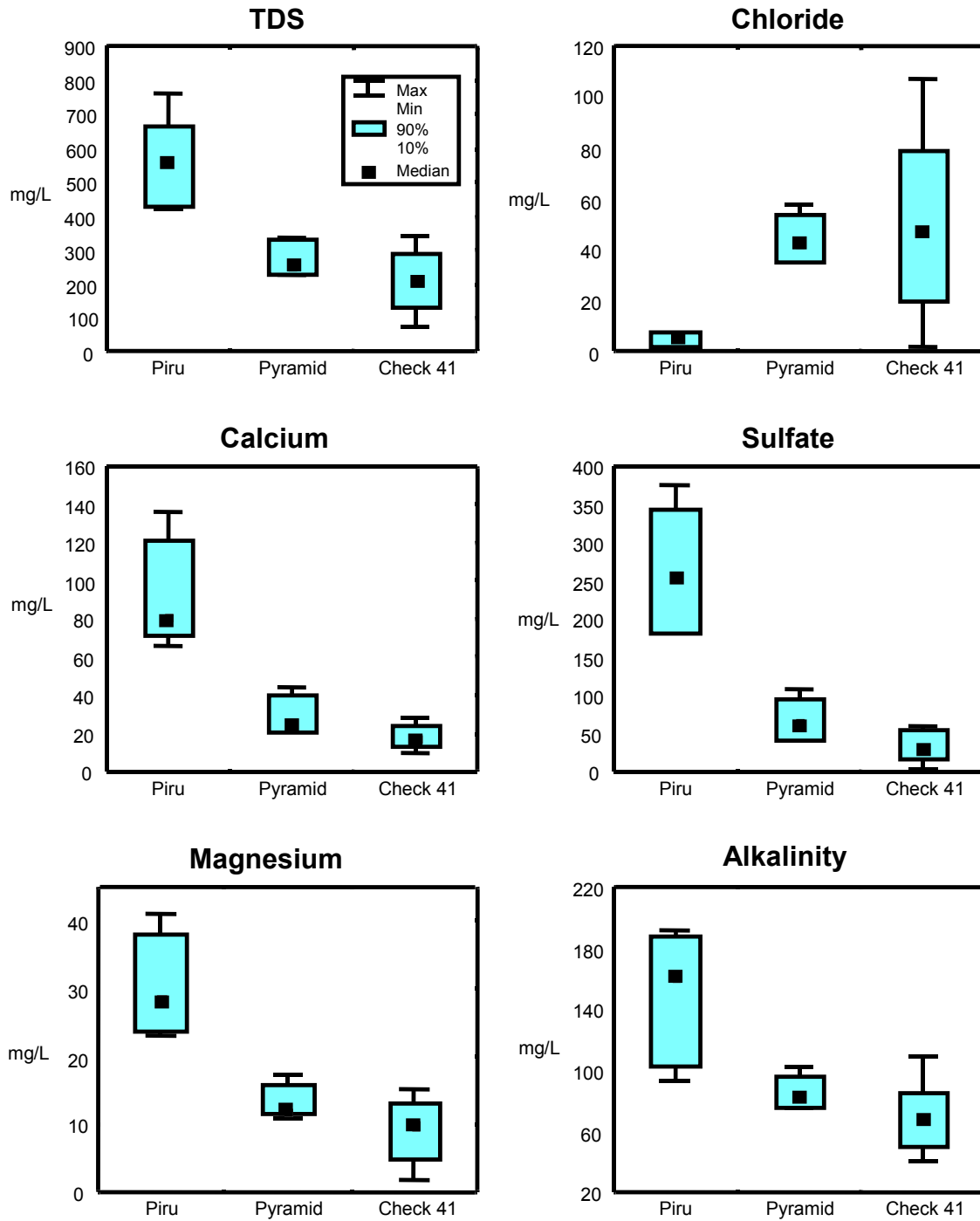
Nutrients such as nitrogen and phosphorus are important water quality parameters because of both their direct effects on water potability and their influence on algal populations in lakes. Because of high nitrogen and phosphorus loading from the SWP, direct runoff and precipitation, all of the Southern California reservoirs are nutrient-rich and would be classified as eutrophic with respect to algal productivity. Nutrient levels indirectly affect water quality in these lakes by stimulating growth of nuisance algae, which are associated with release of taste and odor compounds such as geosmin and 2-methylisoborneol (MIB). High concentrations of certain diatom species can also affect treatment plant operations by clogging filters and interfering with coagulation and flocculation treatments. Eutrophic lakes often experience periods of anoxia in bottom waters because of microbial respiration fueled by periodic die-off of algae. Formation of anoxia is also influenced by lake morphometry, residence time, thermal stratification, and hydrology, particularly the amount and location of water inputs and withdrawals.

Anaerobic water contains elevated concentrations of reduced compounds that require higher doses of oxidants during the treatment process. These reduced compounds are also odorous and bad tasting (for example, hydrogen sulfide) and decrease the aesthetic quality of the water. Metals such as iron, manganese, and certain nutrients are more soluble in anoxic waters owing to low pH.

The occurrence and amount of nuisance algae are controlled by a complex interplay of nutrient loading, species interactions (that is, competition and predation by zooplankton) and physical conditions in the lake, namely temperature and light levels. Nutrient availability is controlled by inputs from source waters and by biological regeneration of nitrogen and phosphorus within the lake and from the bottom sediments. Nutrient levels are typically not limiting for algal growth in the Southern California reservoirs except during summer months (Losee pers. comm. 2001), thus temperature and light are the primary determinants for algal blooms observed in spring and fall.

During spring, the reservoirs typically have low turbidity, good light penetration and no temperature stratification (Coburn, and Losee pers. comm. 2001). As spring progresses, water temperatures rise and stimulate algal growth resulting in a bloom. Decreasing water clarity because of the algal bloom coupled with increasing solar inputs (that is, longer days, higher sun angle) results in thermal stratification of the lake. The warmer (that is, less dense) upper portion of the water column is separated by a thermocline (region of maximum temperature change with depth) from the colder (that is, more dense) lower portion of the water column. The upper portion of the lake is referred to as the epilimnion and is typically well mixed, and light levels are sufficient for algae to grow, thus oxygen levels are high. The portion of the lake below the thermocline is referred to as the hypolimnion and is usually too dark for algal growth. Microbial respiration (that is, consumption of oxygen) fueled by organic materials that sink from the epilimnion (dead algae) and by algal respiration (sinking live algae) can lead to low oxygen levels (hypoxia) or a total depletion of dissolved oxygen (anoxia) in the hypolimnion.

Figure 7-4 Water Quality Summary of Pyramid Lake, Piru Creek, and SWP Inflows, 1996 to 1999



Note: Piru Creek data represents 1994 to 1995 only

By mid to late summer, nutrients have been depleted by algal growth in the epilimnion, and algal biomass declines. Nutrients released by microbial decomposition in the hypolimnion cannot be resupplied to the epilimnion while a strong thermocline persists. Thermal stratification typically persists into fall when surface waters cool and become more dense (they sink) resulting in a lake mixing or turnover event. Wind can also contribute to lake mixing. When the lakes mix, turbidity decreases and nutrients that have accumulated in hypolimnetic waters reach shallower depths in the lakes with sufficient light for algal growth, leading to a fall bloom. Spring and fall algal blooms are commonly observed in all Southern California reservoirs and in temperate lakes throughout the world; however, the specific timing and magnitude of algal blooms vary from year to year and from lake to lake and are difficult to predict.

A more detailed analysis of algal/nutrient dynamics and factors controlling the abundance of nuisance algae in each of the individual SWP reservoirs is beyond the scope of this report. Therefore, this *Sanitary Survey Update* will describe nutrient conditions and noteworthy instances of algal blooms or nuisance algae in each of the Southern California reservoirs. This report does not attempt to determine the causes of algal population dynamics or establish a connection between specific algal blooms and nutrient, light or temperature conditions in the lakes.

The nutrients nitrogen and phosphorus can be high in Pyramid Lake, relative to the other lakes and SWP water. Total nitrogen (defined as Kjeldahl nitrogen plus nitrate+nitrite) peaked at 2.1 mg/L in May of 1996 and averaged 0.4 mg/L (Table 7-3). Nitrate/nitrite values (as N) averaged 0.46 mg/L. The MCL for nitrate in this form is 10 mg/L. Total phosphorus values (as orthophosphate and total phosphorus) were all below 0.1 mg/L (ranging generally from 0.01 to 0.08 mg/L), except for 1 high value of 0.27 mg/L in September 1996. Nutrients are discussed in detail in the Castaic Lake section below because of the recirculation effects described

above and because Castaic is the final water supply use point.

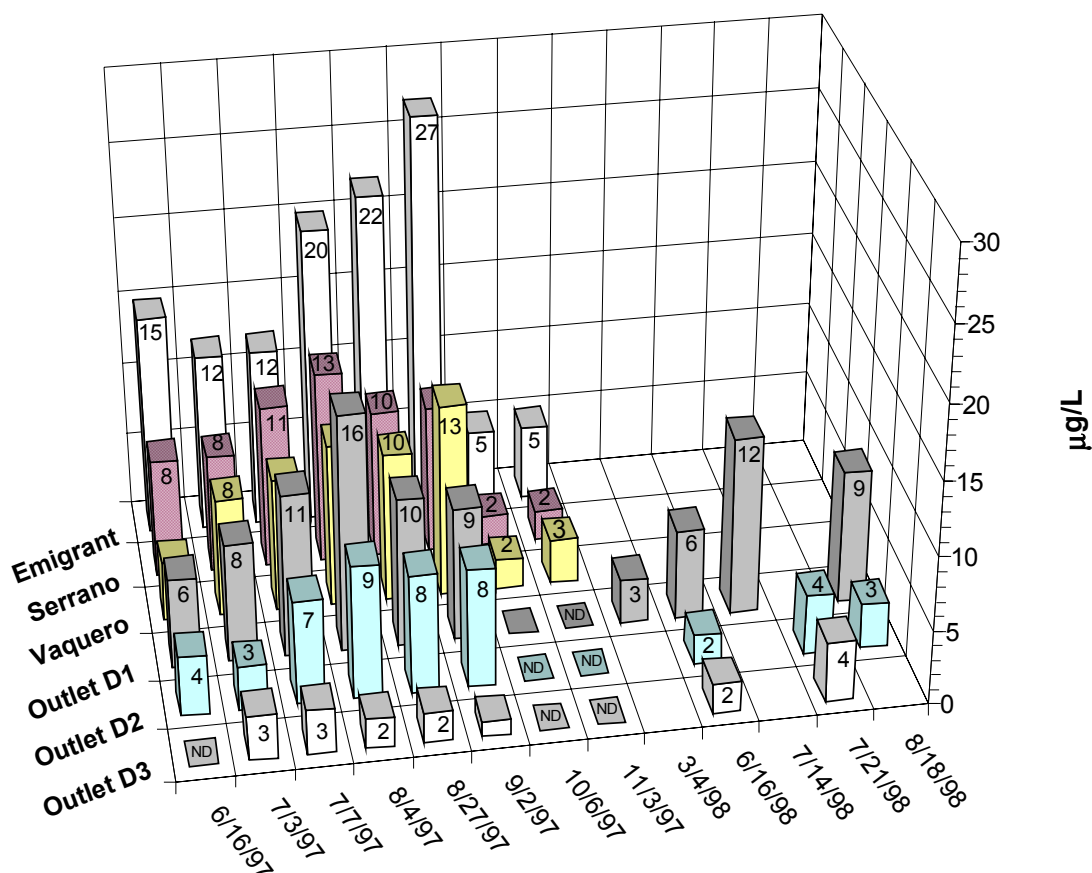
Turbidity

Activities in Hungry Valley recreation area can contribute large sediment loads to Pyramid Lake via Gorman and Piru creeks. Total suspended solids (TSS), soils and particle size analysis, or other erosion indicators currently are not monitored. Turbidity is monitored quarterly, along with other conventional parameters. Turbidities in Pyramid Lake were within the range of SWP inflows and the other lakes, except for 2 high values. High inflows in February 1998 caused the Pyramid Lake turbidity level to reach a high value of 21 NTUs for the period. Another high value of 10 NTUs occurred in August 1996 for unknown reasons. The average turbidity for the period was 3.7 NTUs (Table 7-3).

MTBE

MTBE was sampled at the 3 boat ramps at Pyramid Lake and at the inlet to the Angeles Tunnel (reservoir outlet) (Figure 7-2). The inlet to the Angeles Tunnel was used to represent the open sections of the reservoir. To evaluate the vertical distribution of MTBE, samples at this location were taken at 3 depths: the surface, the lower limit of the epilimnion, and the hypolimnion. During summer months, weak thermal stratification forms in the lake resulting in a shallow thermocline (4 to 12 m). No episodes of hypolimnetic anoxia have been reported for Pyramid Lake.

Results are presented in Figure 7-5. Samples collected at the inlet to the Angeles Tunnel are labeled outlet D1 through D3. Outlet location D1 refers to surface samples collected at depths up to 0.5 meters. Samples collected from the bottom of the epilimnion (4 to 12 meters) are labeled D2. The deep-water samples, collected from the hypolimnion, are labeled D3. In 1997, MTBE was detected in 75% of surface samples taken at the Angeles Tunnel inlet. The range of detected samples was 6 to 16 µg/L, and the mean was 7.4 µg/L. In 1998, surface samples ranged from 3.1 to 12.2 µg/L with a mean of 7.6 µg/L.

Figure 7-5 Summary of MTBE Concentrations in Pyramid Lake

Data sources: DWR 1999, DWR Operations and Maintenance unpublished data 1998

Notes: Outlet D1 = 0-0.5 m, Outlet D2 = 4-12 m, Outlet D3 = >12 m

Samples from the lower limit of the epilimnion ranged from 3 to 9 µg/L with a mean of 4.8 µg/L in 1997. In 1998, values ranged from 2.3 to 4 µg/L, with a mean of 2.9. These values were lower than those detected in the surface samples. Samples from the hypolimnion had the lowest MTBE concentrations. In 1997, MTBE was detected in 5 of 8 samples with a range of 1 to 3 µg/L and a mean of 1.5 µg/L. In 1998, only 2 samples were collected. The MTBE concentrations were 1.7 and 3.5 µg/L.

Surface samples from the Angeles Tunnel exceeded the primary MCL of 13 µg/L only once, on 4 August 1997 (16 µg/L). Surface samples exceeded the secondary MCL of 5 µg/L throughout the summer recreation season in both 1997 and 1998. Samples collected in the hypolimnion were below the secondary MCL throughout the summer recreation season. Samples at all 3 depths followed a similar temporal pattern. MTBE concentrations rose

throughout the summer of 1997, reaching a maximum in July or August and then declined to nondetectable levels by early October 1997.

MTBE concentrations were generally higher near the boat ramps than at the tunnel intake. Samples collected at the boat ramps were taken from the surface only. MTBE concentrations at the Emigrant Landing boat ramp ranged from 5 to 27 µg/L in the summer of 1997 with a mean of 14.7 µg/L. Serrano boat ramp samples ranged from 2 to 13 µg/L with a mean of 8 µg/L. Vaquero boat ramp samples ranged from 2 to 13 µg/L with a mean of 7.5 µg/L. The highest values were observed at the Emigrant Landing boat ramp. Emigrant landing is the largest boat ramp, with 8 lanes compared to 2 at Vaquero. Samples taken at Emigrant Landing exceeded the primary MCL in August and September 1997, with the highest values observed after Labor Day weekend. MTBE concentrations at the boat ramps

fell to levels at or below the secondary MCL by early October 1997.

7.1.4.2 Water Supply System

All water stored at Pyramid Lake is released to the Elderberry Forebay via the Angeles Tunnel. No water is delivered to contractors from Pyramid Lake. Water from the forebay is periodically recirculated back to Pyramid Lake to support power plant operations at the Castaic Powerplant. Water is then released from Elderberry Forebay to Castaic Lake for delivery to SWP contractors.

Pathogens

Pathogen issues were not addressed directly for Pyramid Lake. See Chapter 12 for this information for Castaic Lake and the Jensen FP.

7.1.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

Significant contaminant sources contributing to water quality concerns specific to the Pyramid Lake watershed include recreation, animal populations, crude oil lines, and highway hazardous materials spills. The contribution of TDS and sulfate from Piru Creek is also a watershed issue but is addressed in Section 7.2, Castaic Lake. The water quality problems associated with recreation at Pyramid Lake are the contribution of pathogens, release of MTBE from motorized watercraft, and turbidity caused by erosion in camping areas and Hungry Valley. Pathogens are also potentially contributed by both grazing and wild animals.

Although no ruptures or spills were reported within this period, crude oil lines present a significant potential threat to water quality because of their size and proximity to the lake as well as sensitivity to seismic activity in the area. Pyramid Lake is also vulnerable to highway hazardous materials spills from nearby Interstate 5 and can be affected by return flows from the Elderberry Forebay.

7.1.6 WATERSHED MANAGEMENT PRACTICES

The USDA Forest Service is the primary land manager at Pyramid Lake and its recreation area. California State Parks operates the Hungry Valley Vehicular Recreation Area. The Forest Service has broad authority to manage National Forest lands under the forest planning foundation established in the National Forest Management Act of 1976. Under this Act, the statutory authority to make final decisions for National Forest lands rests with the

Forest Service. The Act is being updated by a new Proposed Rule for the National Forest System Land and Resource Management Planning Act. The proposed rule expands the Forest Service's role to focus on sustainability and collaboration to become a facilitator and information provider, collecting and analyzing relevant information and finding solutions to watershed problems.

There are spill and/or rupture contingency plans for the crude oil lines owned by Pacific Pipeline in its Oil Spill Emergency Response Plan. Oil-absorbent boom logs and pads are maintained at the William E. Warne Powerplant. A portable oil-skimmer is stored at Castaic Lake. There do not appear to be any specific hazardous materials response procedures or on-site facilities at Pyramid Lake for highway spills.

7.2 CASTAIC LAKE

7.2.1 WATERSHED DESCRIPTION

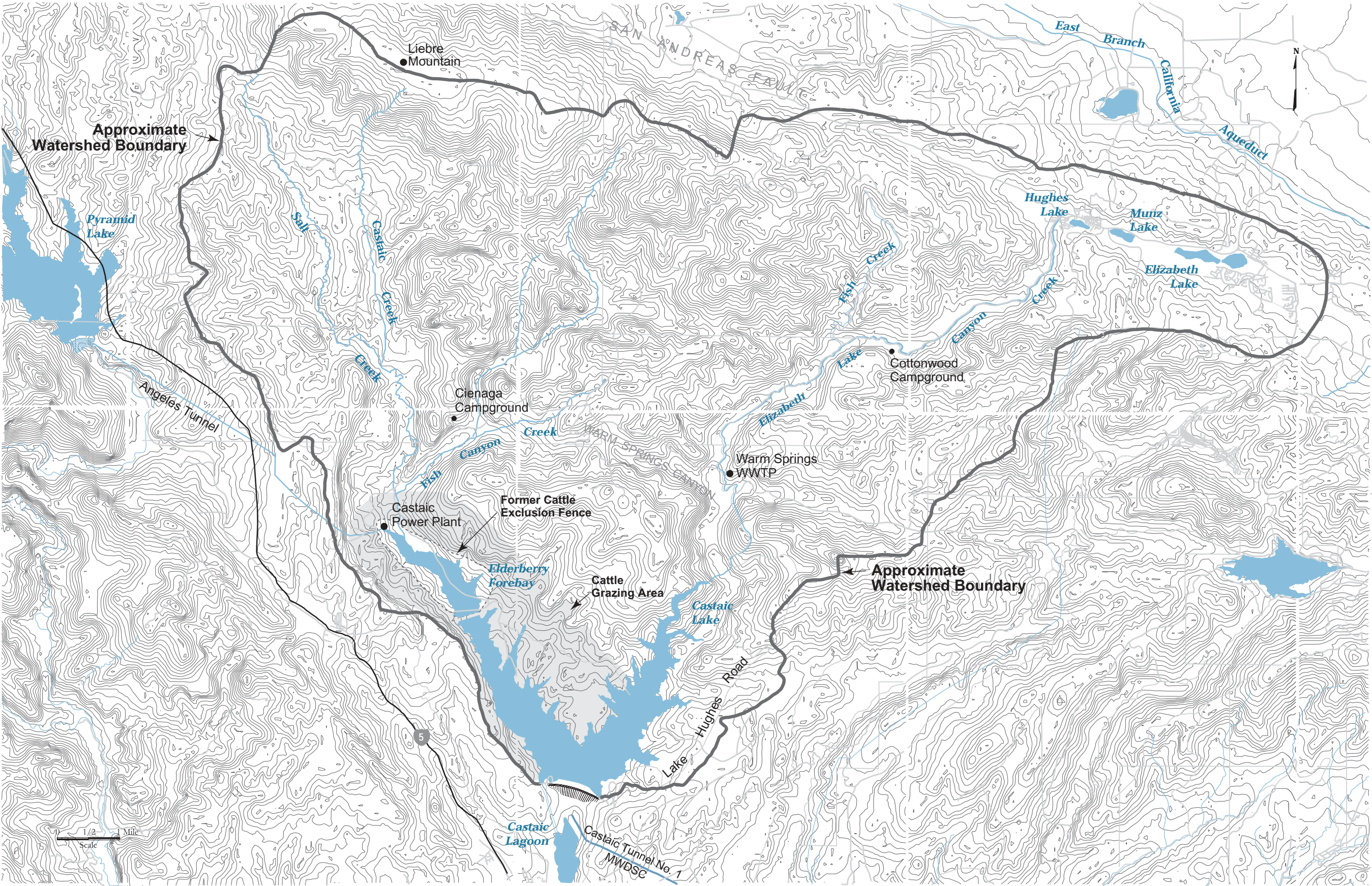
Castaic Lake is in a rugged, mountainous region of Los Angeles County. The lake and its watershed encompass 154 square miles, the 2nd largest of the Southern California SWP reservoirs after Pyramid Lake watershed (Figure 7-6). One of the SWP's largest recreational lakes, Castaic Lake is the terminus of the West Branch of the California Aqueduct. A major feature is the 425-foot tall Castaic Dam. The lake is 2 miles north of the community of Castaic and 45 miles northwest of downtown Los Angeles. Situated in the Liebre Mountains in the southeast part of the Angeles National Forest, Castaic Lake is the former site of a prehistoric Native American Indian settlement.

The Castaic Lake watershed has a Mediterranean climate with hot, dry summers and relatively mild winters. The rainfall period usually begins in November and lasts through April. Historic annual precipitation has been around 16 to 18 inches per year (DWR 1989).

7.2.1.1 Land Use

Information in previous sanitary surveys and from more recent contacts indicates that the watershed is still relatively undeveloped, with the primary land uses being recreation and related activities, cattle and sheep grazing, limited residential development, and some historic mining. Outside the watershed to the south in the upper portion of the Santa Clarita Valley, land has been undergoing significant residential development.

Figure 7-6 Castaic Lake Watershed Area



7.2.1.2 Geology and Soils

The terrain around Castaic Lake is rugged in many areas, with slopes exceeding 25% around most of the upper lake and occasionally exceeding 60%. The watershed is primarily sedimentary rocks of both marine and nonmarine origin of the Castaic Formation in the Ridge Basin region of the San Gabriel Mountains. In the southern portion of the watershed in the vicinity of the lake, rocks consist of sandstone, shale, and conglomerate. Soils in this area in general have a high sand content and are highly erosive, especially along streams. The northern portion of the watershed contains sandstone, shale, and harder rocks such as dolomite limestone, marble, and quartzite. Other than high erosion potential, there are no known natural soil conditions that contribute contaminants of concern in runoff from the watershed.

There are 3 active faults within 3 miles of both the east and west sides of the watershed (DWR 1996). San Andreas Fault lies northeast of the lake just outside the watershed boundary (Figure 7-6). To the west lies the northern portion of the San Gabriel fault. The White Wolf fault in Kern County is about 33 miles north of the dam area. There are also other minor fault traces in the area that mark rock-type boundaries.

7.2.1.3 Vegetation and Wildlife

The environment surrounding the lake consists of riparian vegetation, coastal sage scrub, and chamise chaparral communities mixed with brush and grasses, similar to that found at Pyramid Lake. The upper watershed areas contain native high-desert rangeland and chaparral. The watershed contains numerous wildlife such as mule deer, bobcats, coyotes, and pigs, and smaller mammals such as rabbits and rats typical of brushy, chaparral communities. Parts of the watershed are also within the range of the California Condor.

There are several plant and animal endangered species or species of special concern in the general area, but most findings are not in the Castaic Lake State Recreation Area (SRA). There are findings in San Francisquito Canyon, approximately 4 miles east of the lake and designated an “ecologically sensitive area.” The county of Los Angeles determined that the Castaic Lake SRA and immediately surrounding areas are not ecologically sensitive (DWR 1999a).

7.2.1.4 Hydrology

The watershed drainage into Castaic Lake is relatively large and extensive (154 square miles). There are 2 main sources of natural inflows to Castaic Lake within the watershed boundary, Castaic Creek on the northwest arm and Elizabeth Lake Canyon Creek on the northeast arm (Figure 7-6).

Both creeks only flow seasonally. During summer it is common for creek flows to percolate into the ground because of high sand content and relatively low groundwater table (DWR 1985). The sub-watersheds of each of these major creeks are nearly equal, with the Castaic Creek arm being about 47% of the total area and the Elizabeth Lake Canyon arm being about 53% of the area. Historic average annual natural inflows from the watershed have been estimated to be about 23,000 acre-feet (Brown and Caldwell 1990). Depending on the information source, from one-half (DWR 1999) to two-thirds (Brown and Caldwell 1990) of the natural inflow enters into the Elderberry Forebay via Castaic Creek.

Castaic Creek includes 2 tributaries: Salt Creek and Fish Canyon Creek. Fish Canyon Creek is the larger of the 2 tributaries. Salt Creek joins Castaic Creek in the northwest portion of the watershed, while Fish Canyon Creek joins from the east about one-half mile north of the Castaic Powerplant.

The 2 major tributaries combined can contribute substantial inflow to the lake, although SWP inflow is by far the largest contribution. Average annual inflows from the watershed were estimated in 1995 to be 23,000 acre-feet (DWR 1996). Average winter flows reported in previous studies indicated average flows for Castaic and Fish Canyon Creeks of 32 and 39 cubic feet per second (cfs), respectively (DWR 1985). Because of the soil conditions described above, creek banks in the area are unstable and subject to erosion during high velocity floodflows in winter. Natural inflows to Castaic Lake from 1996 to 1999 are presented in Table 7-4.

Table 7-4 Annual Natural Inflows to Castaic Lake (acre-feet)

1996	1997	1998 ^a	1999
8,934	9,475	97,229	6,439

Source: DWR Division of Operations and Maintenance, SWP Operations Data 1996 to 1999.

^a 43,652 acre-feet total in February 1998 during El Niño storms and 18,457 in May.

Elizabeth Lake Canyon Creek drains the Elizabeth Lake area and includes 1 major tributary—Fish Creek (not to be confused with Fish Canyon Creek). The Elizabeth Lakes complex is at the upper end of the creek and includes Elizabeth, Munz, and Hughes lakes. All are within a reach of 5 miles and drain in series to Elizabeth Lake Canyon Creek (Figure 7-6). During very wet periods, the creek may receive overflow from the lakes complex. Streamflow in Elizabeth Lake Canyon Creek is intermittent, with the main contribution in flow coming from Fish Creek and the other tributaries: Ruby Canyon, Hiatt Canyon, and Tule Canyon Creeks. Peak stream

flows as high as 3,860 cfs have been observed in Elizabeth Lake Canyon Creek (DWR and USDA 1981). The lakes are mostly privately held and support a variety of recreation, including fishing, camping, and some swimming and boating.

The groundwater basin underlying Castaic Lake comes from deep percolation of winter storm runoff into the alluvial aquifer and the underlying Saugus Formation aquifer. During wet years when large amounts of surface water are available, the alluvial aquifer is recharged, and water levels recover as much as 70 feet (DWR 1999a). Groundwater was the primary local water supply source before the SWP.

7.2.2 WATER SUPPLY SYSTEM

7.2.2.1 Description of Aqueduct/SWP Facilities

The Castaic Project was completed in 1972 and provides regulatory storage for water deliveries, emergency water storage, recreational development, power conversion, and fish and wildlife enhancement. Castaic Dam, which is 425 feet high, forms Castaic Lake. The reservoir is the southern terminus of the West Branch of the California Aqueduct at mile 31.55 and receives SWP water from Pyramid Lake via the Angeles Tunnel. Castaic Lake has 323,700 acre-feet of storage capacity, 2,240 acres of surface area, and about 29 miles of shoreline. Immediately downstream of the dam, Castaic Lagoon provides a recreation pool with a constant water surface elevation and functions as a recharge facility for the downstream groundwater basin.

The lake is shaped like a “V” with the 2 main arms branching to the northwest (Castaic Creek arm) and the northeast (Elizabeth Lake Canyon Creek arm) (Figure 7-6). The upper one-third of the Castaic Creek arm is called the Elderberry Forebay. The Elderberry Forebay Dam cuts across the Castaic Creek arm to form the forebay, which has a water surface elevation about 15 feet higher than the rest of the lake. The forebay has 33,000 acre-feet of storage capacity, 500 acres of surface area, and approximately 7 miles of shoreline.

Elderberry Forebay receives water from the Castaic Powerplant and supplies Castaic Lake through an outlet tower. Water from Elderberry Forebay is pumped back into Pyramid Lake via the Angeles Tunnel during off-peak power usage so that power can be generated during peak usage. Castaic Lake receives all of its non-natural inflow from Elderberry Forebay. Water is withdrawn from the lake through a gated outlet tower near Castaic Dam. The water is conveyed downstream to agencies using SWP water as described in Section 7.2.2.2. Some water is also diverted to the Los Angeles County

Department of Parks and Recreation for use around the recreational area.

7.2.2.2 Description of Agencies Using SWP Water

SWP water is withdrawn from Castaic Lake at West Branch mile 31.55 via the Castaic tunnel and distributed to 3 agencies: MWDSC, CLWA, and the Ventura County Flood Control and Water Conservation District (VCFCWCD). The VCFCWCD has an entitlement and an outlet at Castaic Lake but has not built a conveyance system and, therefore, does not take any water.

The West Branch of the California Aqueduct received a smaller amount of SWP water than the East Branch from 1996 to 1999, usually from 37% to 40% of annual deliveries (except 1998) (Table 7-5). East Branch outflow data are also presented for comparison. The total of the 2 branches during the period was typically only 30% to 50% of the total available annual entitlement. Castaic Lake inflows and outflows were generally similar, except for 1998, probably because of the large El Niño storms. Outflows to the contracting agencies, including for Castaic Lagoon and recreational uses, ranged from 269,267 to 367,365 acre-feet.

MWDSC

The MWDSC, whose entitlement of 2,011,500 acre-feet is the largest in the SWP, is a consortium of 27 member agencies and more than 150 subagencies that provide drinking water to nearly 17 million people in parts of Los Angeles, Orange, San Diego, Riverside, San Bernardino, and Ventura counties (DWR and SWC 2000). SWP water from Castaic Lake is delivered via the Foothill Feeder to MWDSC's Joseph Jensen FP, where it is treated and distributed to the San Fernando Valley, Ventura County, central Los Angeles, Santa Monica, and the Palos Verdes Peninsula.

The Jensen FP is in Granada Hills and is the only MWDSC plant on the West Branch that normally treats only SWP water. The plant uses conventional treatment processes consisting of coagulation, ferric chloride addition, sedimentation, filtration, and disinfection. Disinfection has been achieved using chlorine, but the plant is being expanded and will be converted to the use of ozone and chloramines for disinfection in order to control disinfection byproduct (DBP) formation and meet Stage 1 and 2 Disinfectants and Disinfection Byproducts (D/DBP) Rule requirements. The Jensen FP has a current capacity of 750 million gallons per day (mgd), but ozone capacity is 600 mgd.

Table 7-5 SWP Inflow/Outflow for East and West Branches and Reservoirs (acre-feet)

SWP Location	1996	1997	1998	1999
West Branch Outflow	346,654	357,141	124,262	393,160
Castaic Lake:				
Inflow	314,233	334,781	214,431	366,538
Outflow	295,282	336,383	269,267	367,365
East Branch Outflow	490,254	603,691	439,565	607,066
Silverwood Lake:				
Inflow	398,250	495,507	352,561	499,644
Outflow	440,661	443,005	356,851	503,735

Source: DWR Division of Operations and Maintenance, SWP Operations Data 1996 to 1999

CLWA

The CLWA service area encompasses approximately 195 square miles in the Santa Clarita Valley, including portions of unincorporated Los Angeles County, the city of Santa Clarita (including previously unincorporated communities of Newhall, Saugus, and Valencia), Castaic, Val Verde, Castaic Junction, and unincorporated portions of eastern Ventura County. CLWA treats and distributes SWP water to 3 retailers in the Santa Clarita Valley, including the Newhall County Water District, Valencia Water Company, and the Los Angeles County Waterworks District N. 36. CLWA also acquired the Santa Clarita Water Company in October 1999 (McLean pers. comm. 2000).

The CLWA maximum annual SWP entitlement is listed as 107,900, but firm entitlement is considered to be 95,200 acre-feet (McLean pers. comm. 2000a). This includes its original annual entitlement of 54,200 acre-feet, plus an additional annual SWP entitlement of 41,000 acre-feet obtained in 1999 through a water transfer with the Kern County Water Agency.

The CLWA operates 2 surface water treatment plants, the Earl Schmidt FP in Castaic and the Rio Vista Treatment Plant in the city of Santa Clarita. The Earl Schmidt FP has a capacity of 28 mgd and receives raw water via a 54-inch pipeline from the outlet structure normally by gravity. The treatment processes include flash mixing and chemical addition, flocculation and sedimentation, dual media filtration, and chlorine disinfection. The Rio Vista plant has a capacity of 30 mgd and receives raw water from the Foothill Feeder, which is owned and operated by MWDSC, via a 102-inch pipeline. Its treatment plant processes include pre-ozonation, rapid mix and chemical addition, contact clarification (a special process replacing conventional flocculation/sedimentation that biologically reduces DBP precursors), filtration, and primary disinfection

by ozone with secondary disinfection by chlorine (McLean pers. comm. 2000b).

VCFCWCD

The VCFCWCD is the legal entity for the SWP entitlement that is assigned to the Casitas Water District, which in turn also maintains entitlements to the United Water Conservation District and the city of San Buena Ventura. The district has an annual entitlement of 20,000 acre-feet.

7.2.3 POTENTIAL CONTAMINANT SOURCES

7.2.3.1 Recreation

Recreational improvements at Castaic Lake were created and are maintained to fulfill the mandate of the Davis-Dolwig Act to provide such facilities and enhancement of fish and wildlife habitat. The Castaic Lake SRA encompasses about 11,200 acres of land under State and federal ownership and includes the reservoir, Elderberry Forebay, and Castaic Lagoon. With about 29 miles of shoreline, the SRA is an extensive multipurpose recreational area with many activities including boating, riding personal watercraft, water-skiing, windsurfing, fishing, hiking, bicycling, horseback riding, picnicking, camping, park tours, and model plane flying. Once banned from the lake, swimming is now allowed from Memorial Day weekend through Labor Day. Owing to a lack of swim beaches, little or no swimming occurs in upper Castaic Lake. The recreation area is operated by the Los Angeles County Department of Parks and Recreation.

Recreational activities are potential sources of contaminants for several reasons:

- Contribution of feces from body contact recreation such as swimming,
- Introduction of pathogens by horses,
- Fuel spills or leakage from motorized watercraft,
- Spills or leakage from restrooms and wastewater management facilities, and

- Erosion and higher turbidity associated with hiking, horseback riding, or camping, particularly if activities are conducted off established trails and areas.

The major water quality problems associated with recreation at Castaic Lake are the contribution of microbial pathogens *Giardia* and *Cryptosporidium*, release of MTBE from motorized watercraft, and turbidity caused by soil erosion.

Castaic Lake is stocked with bass, trout, and catfish. There are boat rentals and a tackle bait shop. Other recreational activities include hiking and biking trails, picnicking, and playgrounds. Group picnic areas are available for up to 600 persons. Recreational facilities along with important lake features are shown in Figure 7-7.

Recreational use at Castaic Lake follows a seasonal pattern, with 80% of all visitation between April and September and peak attendance occurring on summer weekends. Recreational use for the 1996 to 1999 period (as recreation days) is presented in Table 7-6.

Annual recreational use varied from about 500,000 to 700,000 recreation days from 1996 to 1999. As with Pyramid Lake, Castaic Lake's recreational use declined in 1999 because of several factors, including household economic conditions, water quality, and construction of facility improvements (DWR 1999a). This decline occurred in the early 1990s after recreational use, which was about 900,000 to 1.4 million in the 1980s, dropped to near current levels.

A Castaic Lake use survey conducted in 1989 reported recreation problems that could have contributed to the decline. Problems included conflicts between personal watercraft riders and anglers, poor water quality (for example, dirty lake, debris in water), too many boats on the lake, too many people, no free parking, poor restroom maintenance, and water level fluctuation throughout the year (DWR 1989).

Boating and related water-oriented activity is the most popular recreation at Castaic Lake. There are 3 boat ramp areas around the lake where much of the recreation activity occurs. The main boat ramp (or east ramp area), the largest of the 3, is just east of the dam (Figure 7-7) and includes an 8-lane launch ramp, 3 parking areas, an entrance kiosk, picnic area and

restroom, concessionaire structure, and a 2-lane entrance road (DWR 1999a). The west boat ramp has a 6-lane launch ramp and has similar facilities to the main ramp area, including picnic areas and restrooms. There are also 2 boat-in sites—Sharon's Rest and Laura's Landing—with amenities for boat slips, camping, restrooms, marinas, and picnic areas but no launching facilities.

Campgrounds at Castaic Lake are depicted in Figure 7-7. There are 18 restrooms around the lake and 3 floating restrooms on the lake. Most of the restrooms are within walking distance from the lake, the farthest being about one-eighth of a mile (Yamamoto pers. comm. 2000). Maintenance on the floating restrooms is contracted, and there have been no spills during the period (Coash pers. comm. 1999). Other unnamed recreational areas are equipped with chemical toilets. Sewage handling facilities associated with the campgrounds are discussed under Section 7.2.3.2, Wastewater Treatment/Facilities. Other campgrounds in upper watershed areas are along major creeks. Cienaga and Cottonwood are along Fish Canyon Creek and Elizabeth Lake Canyon Creek above the confluence with Fish Creek, respectively (Figure 7-6).

There have been several completed and in-progress recreation improvements during 1996 to 1999 at Castaic Lake. The largest of these has been at the west ramp boat launching facility and area. The California Department of Boating and Waterways (DBW) designed and funded the improvements. In 1997 DBW funded construction of shoreline erosion control and other general improvements at the west boat launch ramp adjacent to the Castaic Dam right abutment. Construction at the west ramp boating facilities included riprap installation along shoreline for erosion control, lifeguard building additions, and shoreline landscaping between riprap and parking area. Another project in this area was for access road and boat facility improvements and renovations and handicapped access improvements. Additional projects in-progress include a boating instruction and safety center, west ramp parking area improvements, and main ramp area facility renovation/improvements.

Table 7-6 Recreational Use at Castaic Lake

Period	1996	1997	1998	1999
Recreation Days	666,000	684,000	691,000	509,000

Source: Thrapp pers. comm. 2000

Figure 7-7 Castaic Lake



7.2.3.2 Wastewater Treatment/Facilities

Treatment Plant Effluent Discharges

There is a small wastewater treatment plant (WWTP) serving the Warm Springs Rehabilitation Center at 38200 North Lake Hughes Road, which is adjacent to Elizabeth Lake Canyon Creek above the eastern arm of Castaic Lake (Figure 7-6). The WWTP has a design capacity of 30,000 gpd, and all secondary treated wastewater is disposed of by irrigation on 7 acres of land near the WWTP, which is owned by the USDA Forest Service. All sludge and other wastes are hauled off site for disposal. No drainage or disposal is allowed in or near the creek.

The community of Lake Hughes is served by a sewer system and the WWTP. In addition there is another WWTP at the Camp Munz Detention Center, which is operated by Los Angeles County.

The Warm Springs WWTP and disposal facilities are regulated under a National Pollutant Discharge Elimination System (NPDES) permit from the Los Angeles Regional Water Quality Control Board. Both the WWTP and disposal facilities overlie the Santa Clarita Valley Eastern Groundwater Basin and are regulated by the control board to protect the basin's beneficial uses. Regulated parameters include biochemical oxygen demand (BOD), suspended solids, TDS, sulfate, chloride, nitrate, and boron, which are monitored on either a weekly or quarterly basis.

Although the WWTP effluent meets permit requirements for all regulated parameters, several parameters were high or nearly exceeded permit limits during 1997 and 1998. This is probably due to the hardness and mineral content of the groundwater used at the Warm Springs Center. Chloride and sulfate levels were routinely in the 130 and 140 mg/L range, respectively, with the permit limit being 150 mg/L. On most occasions during 1997, sulfate levels were at 150 mg/L. TDS levels were usually about 700 to 720 mg/L, with the limit being 800 mg/L. Also, the total limit of 10 mg/L for various forms of nitrogen was nearly exceeded.

The WWTP is required to submit reports of operations annually to both the control board and the Los Angeles County Health Department. The reports summarize flow, effluent monitoring data, waste volume hauled, and any significant spills, accidents, or operational problems that occurred during the year. Reports were obtained for 1997 and 1998. There were no operational problems or incidents during 1996, 1997, or 1999. During the El Niño floods of 1998, there were operational problems as a result of the storm. Flash floods from the intense storm knocked out power to the sewage lift station and treatment plant. All wastewater and sludge were

contained, and no off-site spillage occurred. Corrective or preventive actions were taken to insure proper treatment and disposal of wastewater (Hayman pers. comm. 1999).

Storage, Transport, and Disposal

All wastewater generated at Castaic Lake is collected and transported outside the watershed for treatment. The Los Angeles County Department of Public Works maintains 5 sewage lift stations within the watershed. There have been no significant spills or incidents with this portion of the collection system since 1996 (Cron pers. comm. 2000). Los Angeles County Department of Parks and Recreation maintains another portion of the wastewater collection system. This portion of the collection system has gravity-fed lines that extend throughout the lake area but are mainly on the west side. There are routine minor problems such as roots in lines or low water pressure plugging lines, but no major stoppages or overflows have reached the lake (Heimbach pers. comm. 2000).

Wastewater is collected and pumped to the main sewage pump station (also called the Ridge Route station) at the south end of Castaic Lagoon (Figure 7-7). From the main pump station, wastewater is transported to the Valencia Water Reclamation Plant in Valencia, which is about 10 miles south of Castaic Lake along Interstate 5 (Cron pers. comm. 2000). The Valencia plant is a tertiary treatment facility with a capacity of 12.6 mgd. It discharges treated effluent to the Santa Clara River (Science App 1998).

Septic Systems

At the rustic boat-in sites Sharon's Rest and Laura's Landing, wastewater handling consists of collection, septic tank treatment, and leach field disposal facilities.

A small septic tank/leach field wastewater system is in use at the Castaic Powerplant at Elderberry Forebay. DWR POC incident reports indicate that approximately 50 gallons of raw sewage spilled into the Elderberry Forebay on 5 November 1996. Presumably, it was from this system. An attempt was made to clean up the spill but no further information was available.

Water quality was reportedly poor during the late 1970s in the Elizabeth Lakes complex because of seepage from local septic systems, presumably associated with developments in the area (DWR and USDA. 1981). However, no recent information was found to document current conditions or to indicate that there are a significant number of septic systems in the watershed.

7.2.3.3 Urban Runoff

Urban runoff from the watershed to the lake is minimal because of the low level of development. It results primarily from recreation-related activities. Drainage from the main boat ramp parking area and probably the other boat ramps flows to Castaic Lake.

Erosion presents a threat to development and use of area facilities. Runoff from surrounding slopes has caused problems adjacent to some existing roads (DWR 1985).

7.2.3.4 Animal Populations

Historically, cattle and sheep have grazed extensively in the watershed (DWR 1996). The grazing season is dependent on rainfall and ranges from several weeks to about 6 months. Both cattle and sheep have been observed grazing to the shoreline at Castaic Lake (MWDSC 2000). Under a cooperative agreement, the USDA Forest Service grazes sheep on DWR property during spring and summer. The agreement specifies that those grazing their sheep must supply water in order to keep sheep out of the lake.

According to a USDA Forest Service employee, grazing has either been recently discontinued or greatly decreased in the overall watershed because an endangered toad was found in Castaic Creek and the fire in the area in 1996 left too much soil uncovered (Bautista pers. comm. 1999). The grasses and weeds that have sprouted since the fire are more subject to erosion than are the deep-rooted fire-adapted native plants.

Although new information on grazing allotments was not available from the Forest Service, it is known that grazing still occurs in the vicinity of Elderberry Forebay. Therefore, it has the potential to contribute pathogens and sediment via erosion to creeks and streams entering the lake as well as along the lake shore. Because of poorly maintained fences, cattle frequently have direct access to the water. Additionally, a fire on 26 August 1996 destroyed several cattle fences in the vicinity of the Elderberry Forebay dock, giving cattle direct access to the lake (Wendt pers. comm. 1996, Quintero pers. comm. 2000). The fences have not been repaired, and cattle have recently been seen in the area (Vecchio pers. comm.). Runoff from creeks in surrounding grazing areas also enters the reservoir during rainy periods. Droppings from grazing animals have been observed being flushed into streams during rains (Quintero pers. comm. 2000). Therefore, this is considered a significant threat to water quality.

There is a substantial but unknown wild animal population in the watershed that is also a likely source of pathogens in creeks and streams entering the lake. The general types of wildlife present in the

watershed were described in Section 7.2.1, Watershed Description.

7.2.3.5 Algal Blooms

Excessive algal growth (that is, blooms) is caused by a combination of optimum temperature and sunlight conditions and an abundance of the nutrients nitrogen and phosphorus, resulting in a condition in reservoirs known as eutrophication or over-enrichment. Algal blooms can produce water quality conditions that disrupt water treatment processes. The primary adverse effects on water quality associated with algal blooms are increased turbidity, which affects plant operations, and taste and odor resulting from production of 2 organic compounds, MIB and geosmin. These 2 compounds are discussed in detail under Section 7.2.4, Water Quality Summary. A summary of algal growth dynamics and reservoir operations was presented within Section 7.1.4.1 under Nutrients.

Nuisance algal growth has been a historic occurrence at Castaic Lake. Nearby MWDSC treatment plants were shut during the mid-1970s because of algal blooms (Brown and Caldwell 1990). In May 1996, a geosmin-producing blue-green algal bloom reduced the efficiency of plant operations. In October 1997, the Jensen FP experienced a dramatic change in raw water quality from Castaic Lake that disrupted plant operation, resulting in higher than normal effluent turbidities. The alga was a microscopic pennate diatom that because of its large size and pencil-like shape was very difficult to treat (MWDSC 2000). The CLWA also reportedly shut down its treatment plant because of the same problem.

Algal blooms are also frequently associated with a change in pH, which can alter the effectiveness of coagulants and other chemicals added to the treatment process and can result in a treatment plant upset. Algal blooms increase treatment costs by increasing turbidity, which fouls filters more quickly and creates compounds that decrease the aesthetic quality of the water.

Copper sulfate is used on lakes for treatment and control of excessive nuisance-algal growth. In June of 1996, 10 tons of copper sulfate were applied to Castaic Lake. This was 50% of the total amount used that fiscal year on all MWDSC reservoirs (MWDSC 1996). Alternative taste and odor management strategies for controlling nuisance algae are being developed to maintain low levels of copper sulfate use (MWDSC 1998).

7.2.3.6 Agricultural Activities

There are no significant agricultural activities in the watershed (Mann pers. comm. 1996).

7.2.3.7 Crude Oil Pipelines

A crude oil pipeline extends into the Castaic Lake watershed from Pyramid Lake (Line #63) and traverses north to south down the east side of Interstate 5 but west of the lake. Most of the pipeline is underground—except at a control station—and is approximately 1 mile away from the lake area. It presents a low threat to Castaic Lake. There have been no releases or spills since *Sanitary Survey Update 1996* (Reese pers. comm. 2000).

7.2.3.8 Mines

The 2 previous sanitary surveys reported the presence of mines in the watershed, but the location, type, and potential for contamination was not known. No new information was found or reported on this activity for this period.

7.2.3.9 Traffic Accidents/Spills

Hydraulic oil leaks from SWP facility operations can be a common occurrence. DWR POC incident reports indicate that on 12 November 1996, 19 gallons of hydraulic oil leaked from the Castaic Intake Tower. Oil booms were placed around the tower to catch the leaked oil. It has been recommended that vegetable oils or water be used as a replacement (MWDSC 2000).

7.2.3.10 Solid or Hazardous Waste Disposal Facilities

There are no known solid or hazardous waste facilities within the Castaic Lake watershed. Private contractors haul solid wastes generated from recreation and other activities at the Castaic Lake SRA and wastes from the CLWA service area to public landfills in Los Angeles County.

7.2.3.11 Geologic Hazards

There are several known faults within 3 miles of both the east and west sides of the watershed. The crude oil pipeline poses a low level threat to water quality but could be susceptible to rupture in the event of an earthquake.

7.2.3.12 Fires

Fires in the watershed, though infrequent, have caused turbidity problems in the lake (Brown and Caldwell 1990). On 26 August 1996, a fire occurred near the Elderberry Forebay boat dock and burned 22,500 acres, along with several fences intended to prevent grazing cattle from having direct access to the lake. The fire also burned structures and feed supplies on the Cordova Ranch, which is adjacent to DWR land around the forebay and to which the cattle belong. The fences were not repaired, and, therefore, cattle had direct access to the shoreline in this area. Increased turbidities were observed at the Jensen FP after the first rains in the fall of 1997. According to USDA Forest Service staff, cattle also had direct

access to the water prior to the fire because of poorly maintained fences, and access has only increased since the fire. The cattle had an existing water supply on the ranch and did not need the lake for drinking water (Wendt pers. comm. 1996).

There were no specific reports of problems other than the fencing associated with the fire. However, in addition to the substantial increase in erosion potential because of steep terrain and sandy soils at Castaic Lake, grazing cattle also erode the banks of the shoreline and can contribute pathogens directly to the water. No information was available on follow-up actions or mitigation or the current state of fencing and shoreline protection at Castaic Lake.

7.2.3.13 Population/General Urban Area Increase

The Castaic Lake watershed itself appears to remain relatively undeveloped, except for recreation facilities and a small portion of the Elizabeth Lake area. However, there is some residential development occurring around the lake. The North Lake development project is proposed on a bluff overlooking the west lake area and is within the watershed of Castaic Lagoons (Quintero pers. comm. 2000).

Outside the watershed and south of the lake in the Santa Clarita Valley, a proposed Newhall Ranch development would cover 12,000 acres of land, create 24,000 units of housing, and add about 70,000 people to the area. Environmental documents also state that there is no firm water supply for the project. This level of very substantial growth could affect recreation and other infrastructure and have other indirect effects on the SRA.

The Newhall Ranch project would be in the CLWA service area. CLWA prepared an initial study in April 2000 to obtain the transfer of 10,000 acre-feet of SWP water from the Kern County Water Agency, to be held in reserve for use in developments owned by the Newhall Land and Farming Company (land owner for Newhall Ranch). The initial study concluded that the project could significantly affect the environment, and an environmental impact report was required (CLWA 2000). The project, facing opposition from local area residents, is on hold pending further environmental review (McLean pers. comm. 2000b).

7.2.3.14 Land Use Changes

The only known land use changes associated with construction or development were recreation-related improvement projects described in Section 7.2.3.1, Recreation. There were no other known major land use changes in the watershed.

7.2.4 WATER QUALITY SUMMARY

7.2.4.1 Watershed

Water quality data for Castaic Lake for the 1996 to 1999 period are presented in Table 7-7. These data were collected by DWR's Division of Operations and Maintenance (O&M) at the Castaic Lake outlet. All parameters were below drinking water MCLs or applicable Article 19 objectives for this period, except for hardness on 2 occasions in February and August of 1996. Hardness values during these periods were 192 and 189 mg/L, respectively, which exceeded the Article 19 value of 180 mg/L.

Castaic Lake is affected by the water quality of outflow from Pyramid Lake and the Elderberry Forebay (for example, high sulfate and TDS) and from inputs from several small streams within its

watershed, particularly Castaic Creek. Data and information collected for this reporting period indicate that there are several water quality concerns, namely, TDS, nutrients, turbidity, DBPs, MTBE, taste and odor, and pathogens.

Minor elements (for example, trace elements) that were detected in at least 1 or more samples but at low levels included arsenic, barium, boron, chromium, copper, and zinc (Table 7-7). Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations as the detection limit. However, statistics were not calculated for parameters with 2 or fewer detections. Arsenic was consistently detected but only at 0.002 mg/L, just above the detection limit of 0.001 mg/L.

Table 7-7 Castaic Lake (Lake Outlet) Feb 1996 through Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection limit	# of Detects/ Samples
Minerals							
Calcium	38	38	30	45	32-43	1	16/16
Chloride	46	45	41	54	42-52	1	16/16
Total Dissolved Solids	319	316	266	406	270-388	1	17/17
Hardness (as CaCO ₃)	161	162	128	192	140-185	1	16/16
Alkalinity (as CaCO ₃)	99	99	84	114	88-111	1	16/16
Conductivity (µS/cm)	535	527	479	627	484-604	1	16/16
Magnesium	16	16	13	19	14-19	1	16/16
Sulfate	97	96	70	129	79-126	1	16/16
Turbidity (NTU)	2	1	<1	3	<1-3	1	7/14
Minor Elements							
Arsenic	0.002	0.002	0.002	0.002	0.002-0.002	0.001	17/17
Barium	0.05	0.05	<0.05	0.05	<0.05-0.05	0.05	1/17
Boron	0.3	0.4	0.3	0.4	0.3-0.4	0.1	16/16
Chromium	0.005	0.005	<0.005	0.007	<0.005-0.006	0.005	4/17
Copper	0.005	0.005	0.002	0.014	0.002-0.009	0.001	13/17
Zinc	0.005	0.005	<0.005	0.010	<0.005-0.005	0.005	1/17
Nutrients							
Total Kjeldahl Nitrogen(as N)	0.4	0.4	0.2	0.8	0.2-0.5	0.1	27/27
Nitrate (as NO ₃)	0.7	0.8	<0.1	1.8	<0.1-1.6	0.1	9/16
Nitrate+Nitrite (as N)	0.16	0.10	<0.01	0.50	<0.01-0.38	0.01	36/48
Total Phosphorus	0.03	0.03	0.01	0.09	0.02-0.06	0.01	48/48
Orthophosphate	0.02	0.01	<0.01	0.06	<0.01-0.04	0.01	19/48
Misc.							
Bromide	0.13	0.13	0.12	0.15	0.12-0.14	0.01	4/4
Total Organic Carbon	4.0	3.5	2.5	7.7	2.8-5.8	0.1	16/16
pH (pH unit)	8.3	8.2	7.4	9.1	7.7-9.1	0.1	16/16
UVA abs. @ 254 nm (cm ⁻¹)	0.069	0.069	0.061	0.076	0.062-0.073	0.001	8/8

Source: DWR O&M Division database, May 2000

Notes: Bromide data from Nov 1998 - Aug 1999 only

pH and UVA data from Feb 1998 - Nov 1999 only

Total Dissolved Solids

TDS concentrations in Castaic Lake during 1996 to 1999 were higher than in Pyramid Lake and Check 41, ranging from 266 to 406 mg/L and averaging 319 mg/L (Table 7-7). TDS levels (1971 to 1996 data) in Castaic Lake were also similarly high, ranging from 207 to 471 mg/L and averaging 328 mg/L (DWR 1996a).

In the discussion of Pyramid Lake in Section 7.1, it was noted that in high natural inflow years such as 1996 and 1998, sulfate and hardness typically increase by May and decrease during summer, depending on the volume of SWP inflows, because of the strong influence of Piru Creek. The high TDS levels in Piru Creek are due to the high sulfate/bicarbonate composition of the watershed. Average sulfate concentrations in Piru Creek (554 mg/L) are 8 times higher than SWP water. There were high TDS levels during early 1996 that were due to unusually high inflows from Piru Creek in 1995. TDS, sulfate, and hardness declined steadily during 1996 because of large SWP inflows. Similarly high sulfate (280-425 mg/L) and TDS values were also observed in Castaic Creek.

These effects and trends were also observed in Castaic Lake, suggesting that Piru Creek has an appreciable affect on downstream water quality. TDS levels progressively increased from SWP

inflows at Check 41 to Pyramid Lake and on to Castaic Lake, as seen in Figure 7-8 a-c.

Most of the high TDS and sulfate values in Castaic Lake occurred in 1996 (along with the hardness problems described above) and some values in 1999 (Table 7-8). The 5 highest values out of 17 samples collected for each parameter occurred in 1996 and 1999. This appears to be related to the influence of extremely high TDS/sulfate loads in inflows from Piru Creek inflows to Pyramid Lake in 1995 and again in 1998.

This connection is further suggested by a comparison of regression analyses of TDS and sulfate for both lakes (Figure 7-9). The regressions for Pyramid and Castaic Lake show a similar slope and grouping, while the Check 41 (above Pyramid Lake) regression shows a much different grouping pattern

Table 7-8 Highest TDS and Sulfate Values in Castaic Lake (mg/L)

Month/Year	TDS	Month/Year	Sulfate
Feb 1996	406	Feb 1996	129
Aug 1996	390	Aug 1996	128
May 1996	386	May 1996	123
May 1999	347	May 1999	97
Nov 1996	331	Nov 1996	102

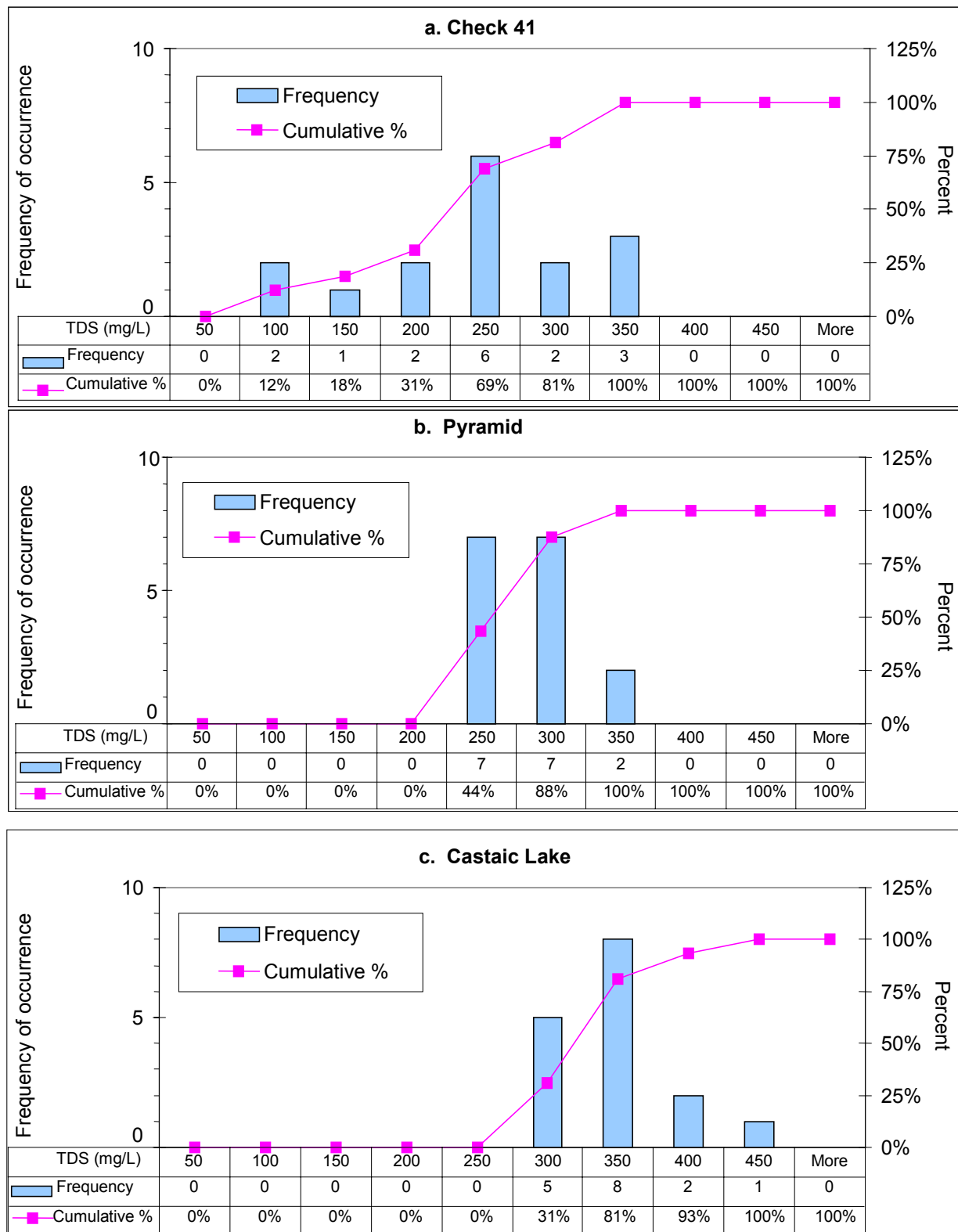
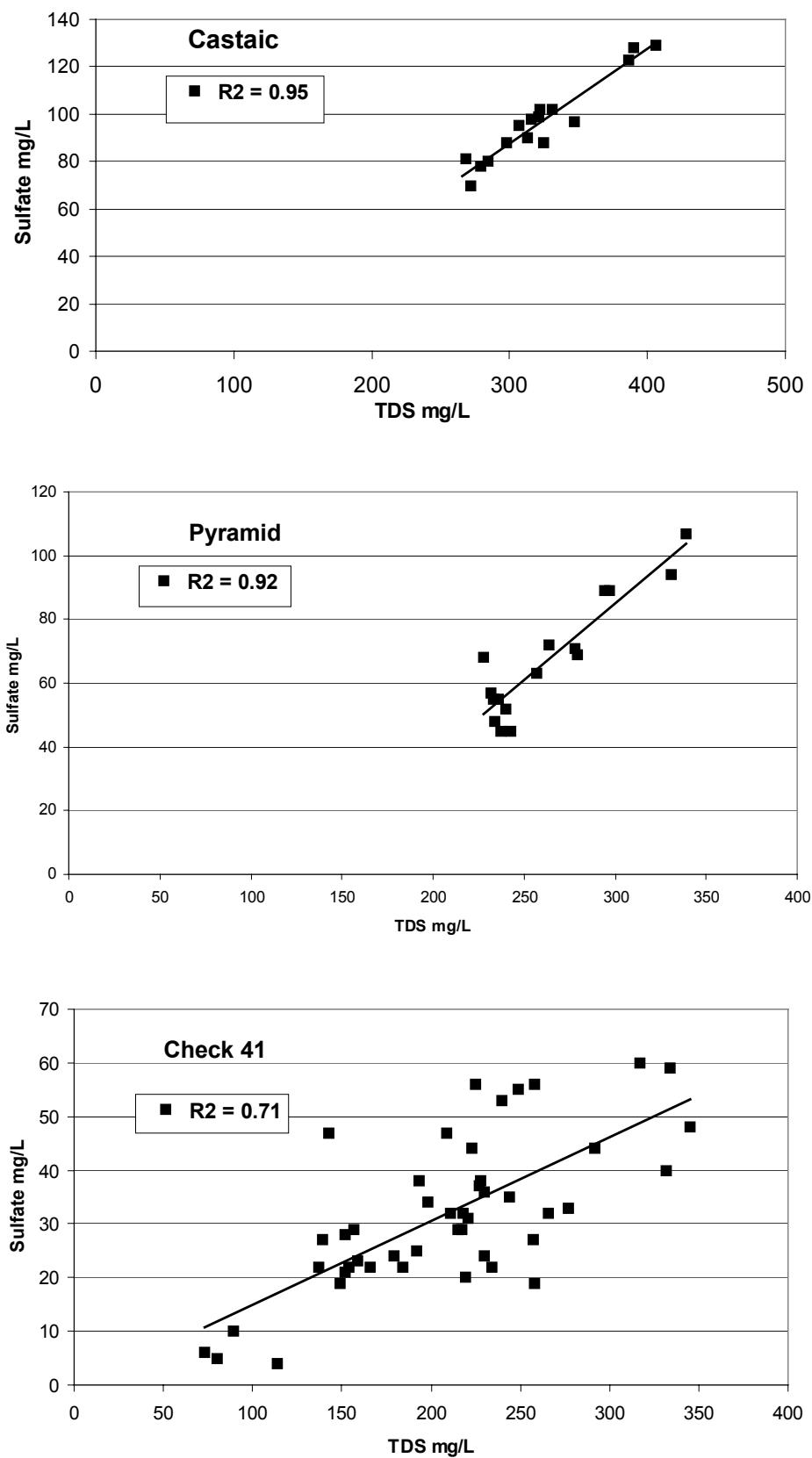
Figure 7-8a-c Cumulative Probability Distribution of TDS at Check 41, Pyramid Lake, and Castaic Lake, 1996 to 1999

Figure 7-9 TDS vs. Sulfate in Pyramid, Castaic, and Check 41



Nutrients

Nutrient levels in Castaic Lake were lower than both SWP inflows at Check 41 and Pyramid Lake, with a pattern of decreasing concentration evident from one to the next (Figure 7-10). The reason for this observation is unknown, although it could be because of increased algal utilization in Castaic Lake. Total phosphorus levels ranged from 0.01 to 0.09 mg/L, averaging 0.033 mg/L (Table 7-7). Orthophosphate levels ranged from <0.01 to 0.06 mg/L, averaging 0.017 mg/L and detected in

only 19 of 48 samples. Kjeldahl nitrogen levels (as N) ranged from 0.2 to 0.8 mg/L, averaging 0.39 mg/L. Nitrate and nitrite levels (as N) ranged from <0.01 to 0.5 mg/L and averaged 0.16 mg/L. Both forms of phosphorus, total and orthophosphate, and nitrate and nitrite followed a seasonal pattern of winter increase and summer decrease (Figure 7-11). The phenomenon is caused by lake turnover and algal uptake rates (see Nutrients under Pyramid Lake Section 7.1.4.1).

Figure 7-10 Nutrient Concentrations at Check 41 and West Branch Lakes

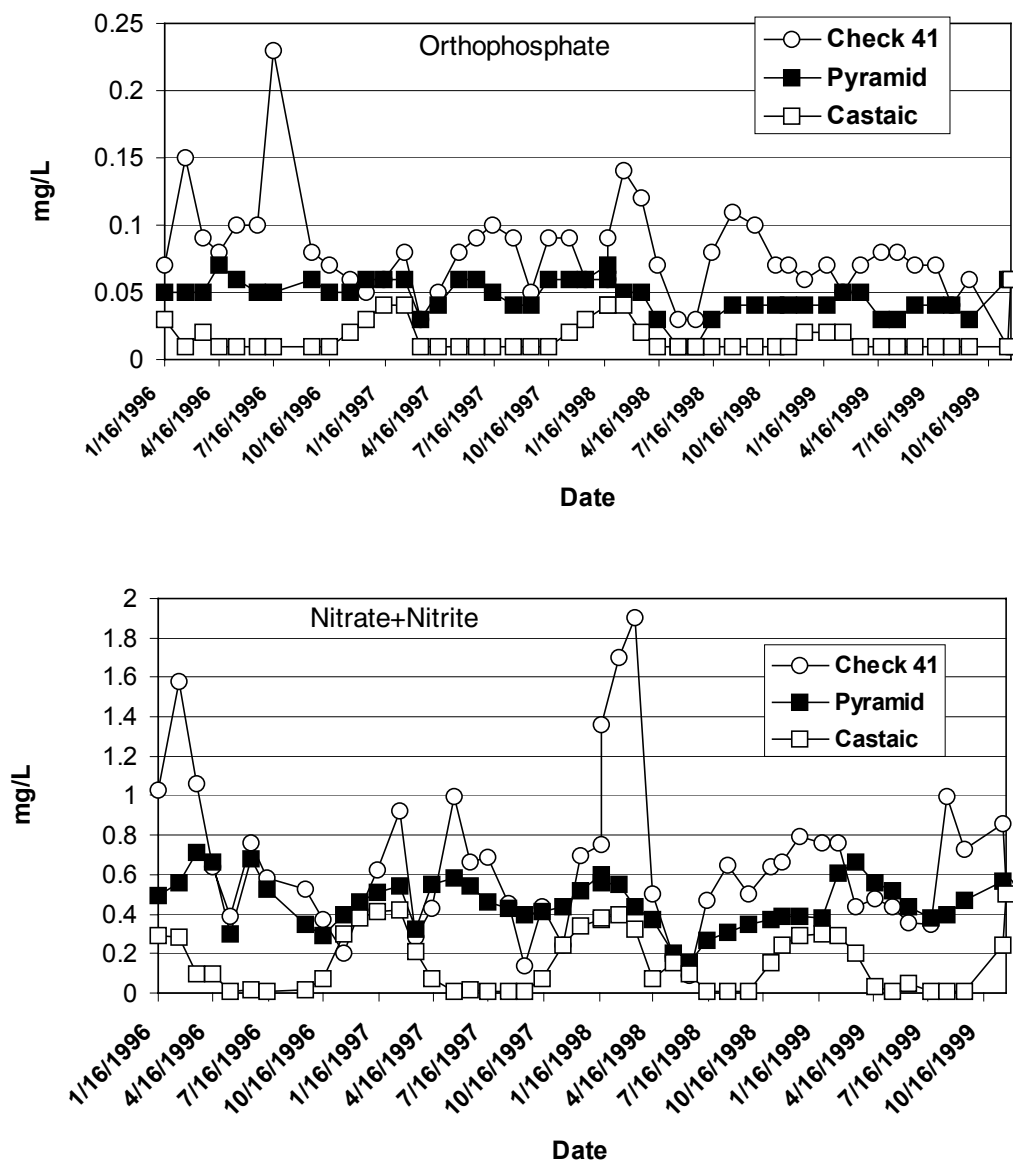
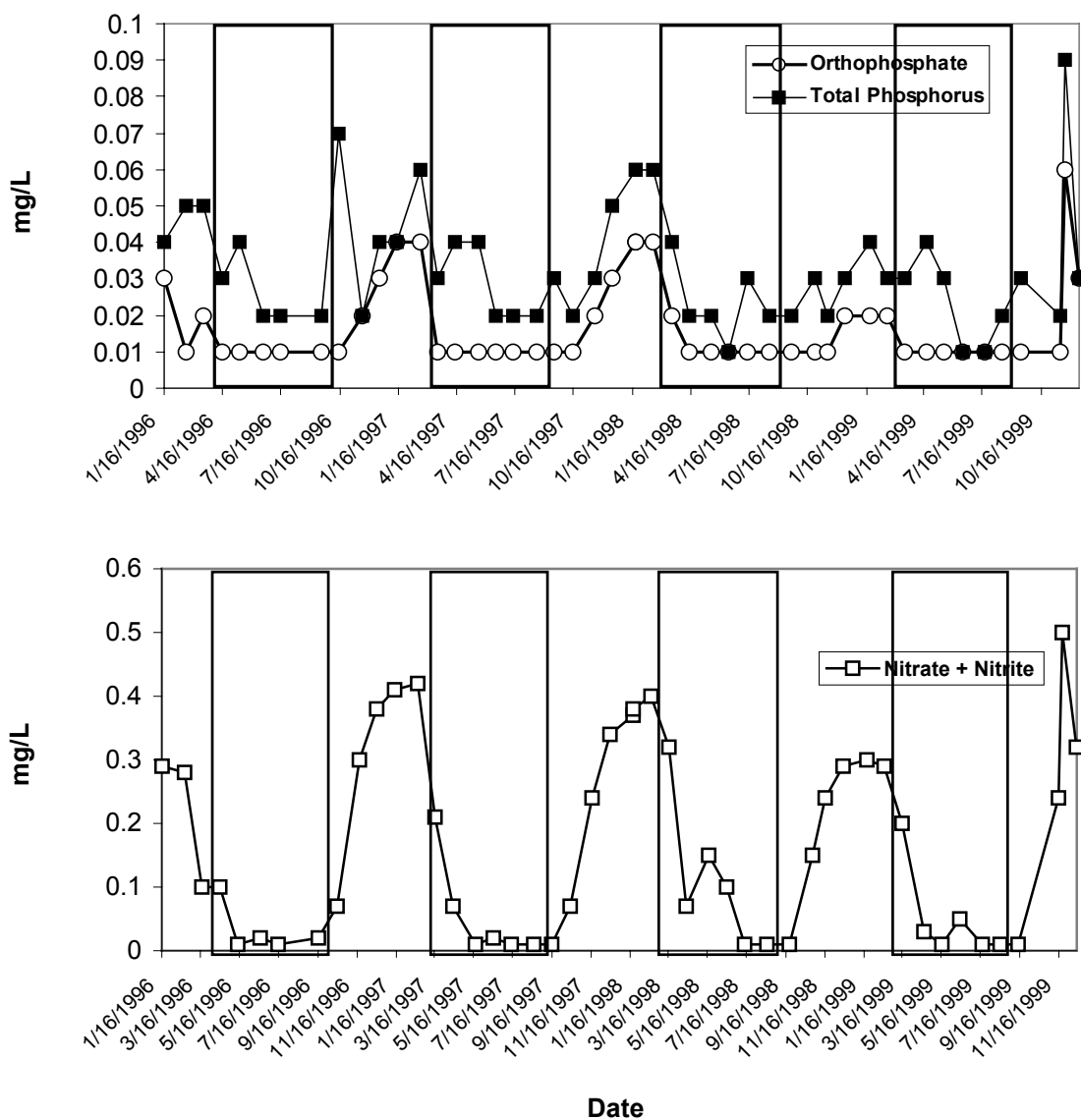


Figure 7-11 Seasonal Variation in Nutrient Concentrations in Castaic Lake, 1996 to 1999

Source: DWR Operations and Maintenance database
 Boxed areas represent approximate algal growing season

Turbidity

Activities in the recreation areas can contribute to erosion, given the highly erosive soils around Castaic Lake. Algal blooms can also cause increased turbidity. This is discussed under Section 7.2.2, Water Supply System. Turbidity is also an issue associated with pathogens because of its effect on disinfection efficiency.

Turbidity is monitored quarterly, along with other conventional parameters. Turbidity in Castaic Lake

was much lower than SWP inflows and Pyramid Lake, ranging from 1 to 3 NTUs (Table 7-7). Pyramid Lake settles out the majority of the SWP inflow turbidity. However, the effects of these activities could be masked because of the sampling location or settling capacity of the lake or both.

Total Organic Carbon and Alkalinity (DBP precursors)

Total organic carbon (TOC) concentrations at Castaic Lake from 1996 to 1999 ranged from 2.5 to

7.7 mg/L and averaged 3.97 mg/L (Table 7-7). Alkalinity ranged from 84 to 114 mg/L and averaged 98.7 mg/L. These values are based on only 16 samples collected quarterly, as with other conventional parameters.

TOC values appear to be largely affected by SWP inflow quality at Check 41 (Table 7-9). The 5 highest TOC values between 1996 through 1999 at Castaic Lake occurred in 1996, 1997, and 1999. As shown in Table 7-9 and in Figure 7-12, values at Castaic Lake commonly fell 1 month, and no more than 2 months, after the high value at Check 41, and appear to correlate with high levels in SWP inflows.

High TOC levels in 1996 were the result of early and late season runoff in the Central Valley (that is, floodwater inflows in the San Luis Canal) and at Check 41. Total Trihalomethane Formation Potential (TTHMFP) levels were also high during the same periods, and were composed of mostly chloroform and bromodichloromethane (DWR 1999).

The highest TOC value was found in February 1999, following a very high TOC sample in January 1999 at Check 41. The very high value of 9.3 mg/L at Check 41 in January 1999 was unusual because upstream floodwater and non-SWP inflows were absent that month. It was suspected that a short-

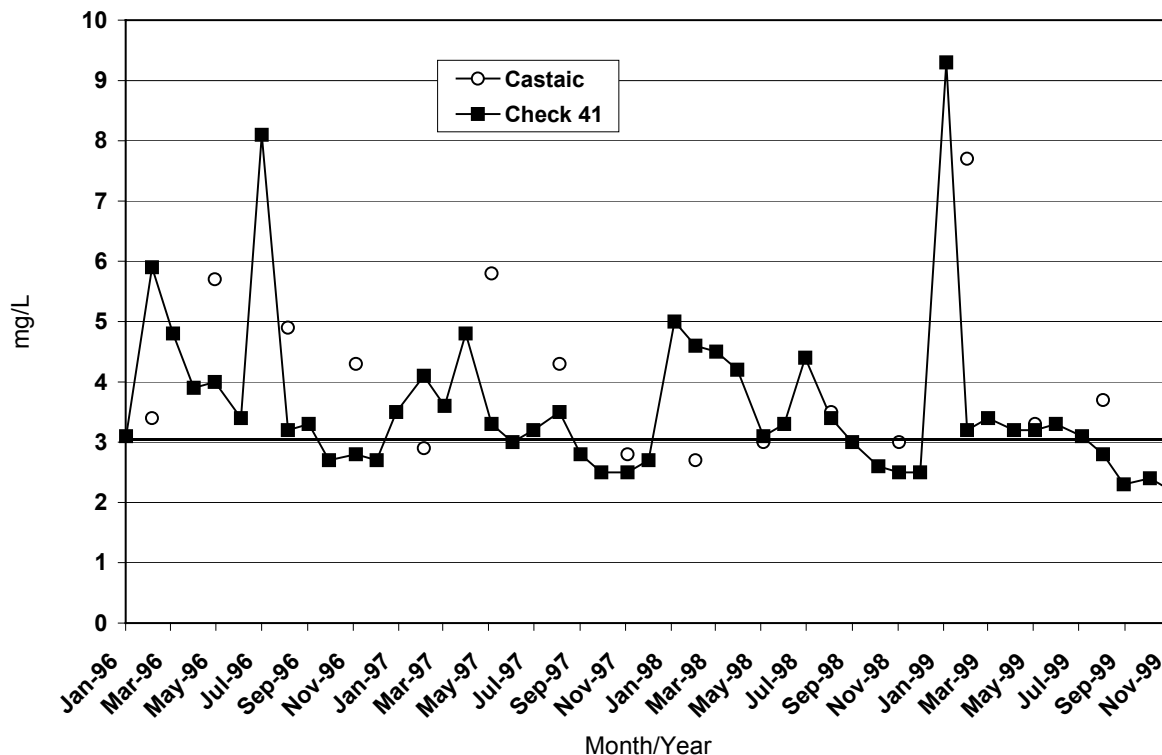
duration slug of TOC from the Delta that passed Check 41 at the time of sampling was the cause. Natural inflow to Castaic Lake was probably not the source of the high TOC value of 7.7 mg/L because there was no corresponding increase observed in 1998 when natural inflow accounted for 41% of all inflows (and <1% in 1999) (DWR 2000).

As with Check 41, Castaic Lake TOC levels frequently exceeded the proposed drinking water protection standard of 3 mg/L at the export pumps at Banks Pumping Plant (Figure 7-12). With alkalinity in the 60 to 120 mg/L range, the high TOC levels would still require some removal by water supply agencies, as specified in the proposed TOC removal requirements under the D/DBP Rule. Bromide levels in Castaic Lake ranged from 0.12 to 0.14 mg/L, within the range of values for Check 41, and averaged 0.13 mg/L, also similar to Check 41. Only 4 samples were collected because sampling was only begun in 1998. These values also exceed the proposed drinking water protection standard of 0.05 mg/L for bromide. Both of these parameter levels are a reflection of Delta contaminant sources and water quality conditions.

Table 7-9 Comparison of TOC at Check 41 and Castaic Lake

Check 41		Castaic Lake	
Month/Year	TOC (mg/L)	Month/Year	TOC (mg/L)
Feb 1996	5.9	May 1996	5.7
Mar 1996	4.8	Aug 1996	4.9
Jul 1996	8.1	Nov 1996	4.3
Apr 1997	4.8	May 1997	5.8
Jan 1999	9.3	Feb 1999	7.7

Figure 7-12 TOC Concentrations at Castaic Lake and Check 41



MTBE

The MWDSC performed sampling at Castaic Lake from summer 1996 to summer 1998. MWDSC sampled 3 locations, the lake inlet, the lake outlet, and the main boat ramp. DWR sampled 3 locations during the summer recreation seasons of 1997 and 1998: the lake outlet, the main boat ramp, and the west boat ramp. Surface samples were collected at all locations. Mid-depth and deep water samples were also collected at the lake outlet to evaluate the vertical distribution of MTBE in the water column. The mid-depth samples were collected at the bottom of the epilimnion, just above the thermocline. The deep water samples were collected within the hypolimnion. Results are presented in Table 7-10.

Castaic Lake was thermally stratified during the summer of 1997. The thermocline divided the epilimnion from the hypolimnion from June through September. The depth to the thermocline varied from approximately 8 to 12 meters.

MTBE concentrations in Castaic Lake were higher than other reservoirs with lower recreational use. MTBE concentrations in surface samples began to rise in the early summer as recreation increased. Surface values routinely exceeded the primary MCL of 13 µg/L during the summer months. MTBE concentrations declined in the winter months to levels below the secondary MCL of 5 µg/L. The deep water samples remained below the secondary MCL through the summer recreation season.

The main boat ramp exhibited higher MTBE concentrations than the west boat ramp, probably because the main ramp has 18 boat lanes while the west ramp has only 6 lanes. DWR sampling revealed that MTBE concentrations at the main boat ramp ranged from 9.7 to 22.0 µg/L. The mean was 16.2 µg/L. MTBE concentrations at the west boat ramp ranged from 3.1 to 15 µg/L. The mean was 11.1 µg/L. These data are based on 8 samples collected by DWR between June 1997 and November 1997.

MWDSC and DWR collected 33 surface samples at the outlet tower between October 1996 and

October 1998. MTBE concentrations in MWDSC samples ranged from 1 to 29 µg/L with a mean of 8.9 µg/L (Table 7-10). DWR samples ranged from 1 to 24 µg/L, with a mean of 8.6 µg/L. These and other DWR samples (at the boat ramps) are presented in Figure 7-13. The 2 highest values in both datasets, 24 and 29 µg/L, were detected immediately following

the 4th of July weekend in 1997. The 3rd highest value, 20.8 µg/L, was observed after the 4th of July weekend in 1998. Excluding these high values, the overall mean concentration at the outlet was 6.8 µg/L.

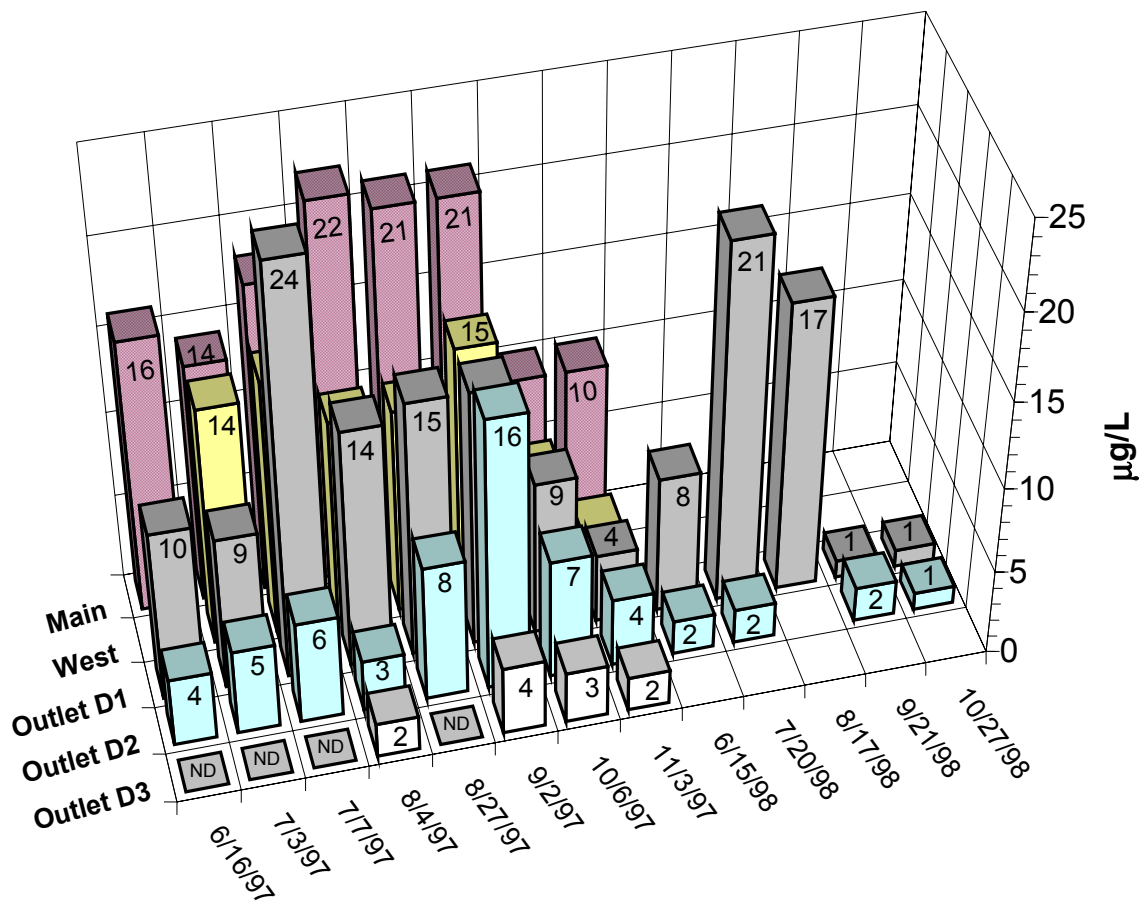
Table 7-10 Summary of MTBE Concentrations in Castaic Lake (µg/L)

MWDSC Sampling	Outlet (1997)		Main Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion)				
Range	2.0 to 29	ND to 2.6	1.0 to 20	ND to 3.8
Mean	8.9	1.0	7.7	1.3
Bottom (Hypolimnion)				
Range	ND to 2.3	N/S	N/S	N/S
Mean	1.0	N/S	N/S	N/S

DWR Sampling	Outlet (1997-98)		Main Boat Ramp (1997)		West Boat Ramp (1997)	
	Summer	Winter	Summer	Winter	Summer	Winter
Surface (Epilimnion D1+D2)						
Range	1.0 to 24	N/S	9.7 to 22	N/S	3.1 to 15	N/S
Mean	8.6	N/S	16.9	N/S	11.1	N/S
Bottom (Hypolimnion)						
Range	ND to 4.0	N/S	N/S	N/S	N/S	N/S
Mean	2.8	N/S	N/S	N/S	N/S	N/S

Notes: Surface samples include samples collected from 0.5 to 15 meters
 ND = Not Detected, N/S = Not Sampled

Figure 7-13 Summary of MTBE Concentrations in Castaic Lake



Data source: DWR 1999, DWR Operations and Maintenance unpublished data 1998

Notes: Outlet D1 = 0.5 m, Outlet D2 = 7-10 m, Outlet D3 = >18 m

MTBE concentrations in samples collected from the lower portion of the epilimnion ranged from 3.3 to 16.0 µg/L. The mean was 6.6 µg/L out of 8 samples. MTBE was only detected in 4 of the 8 DWR samples from the hypolimnion in summer. When detected, MTBE ranged from 2 to 4 µg/L and averaged 1.3 µg/L. The high value of 4 µg/L (DWR data) was observed in early September as the thermal stratification was weakening and the epilimnion and hypolimnion began to mix. MWDSC data concur with DWR values.

Surface samples were collected at the outlet tower and boat ramps before and after the 4th of July and Labor Day weekends in 1997 (not shown in table). These 2 weekends represent the periods of highest recreational use at the lake. Over the 4th of July weekend, MTBE concentrations increased from 9 to 24 µg/L at the outlet tower. The outlet tower lies close to the area of the lake reserved for personal

watercraft use (Figure 7-7). The boat ramps exhibited less of an increase. The main boat ramp increased from 14 to 15 µg/L and the west boat ramp increased from 12 to 18 µg/L.

A group of compounds commonly associated with fuel contamination, benzene, toluene, ethyl benzene, and xylene (BTEX), and MTBE were detected together in only 14% of the 39 surface samples that DWR collected from the boat ramps and outlet tower in 1997. Because BTEX is not mobile in the water column, its presence indicates local contamination by gasoline. MTBE and BTEX were detected together in 7 out of 8 surface samples taken at the main boat ramp. This number dropped to 2 out of 7 at the west boat ramp and 3 out of 8 at the outlet tower.

Taste and Odor

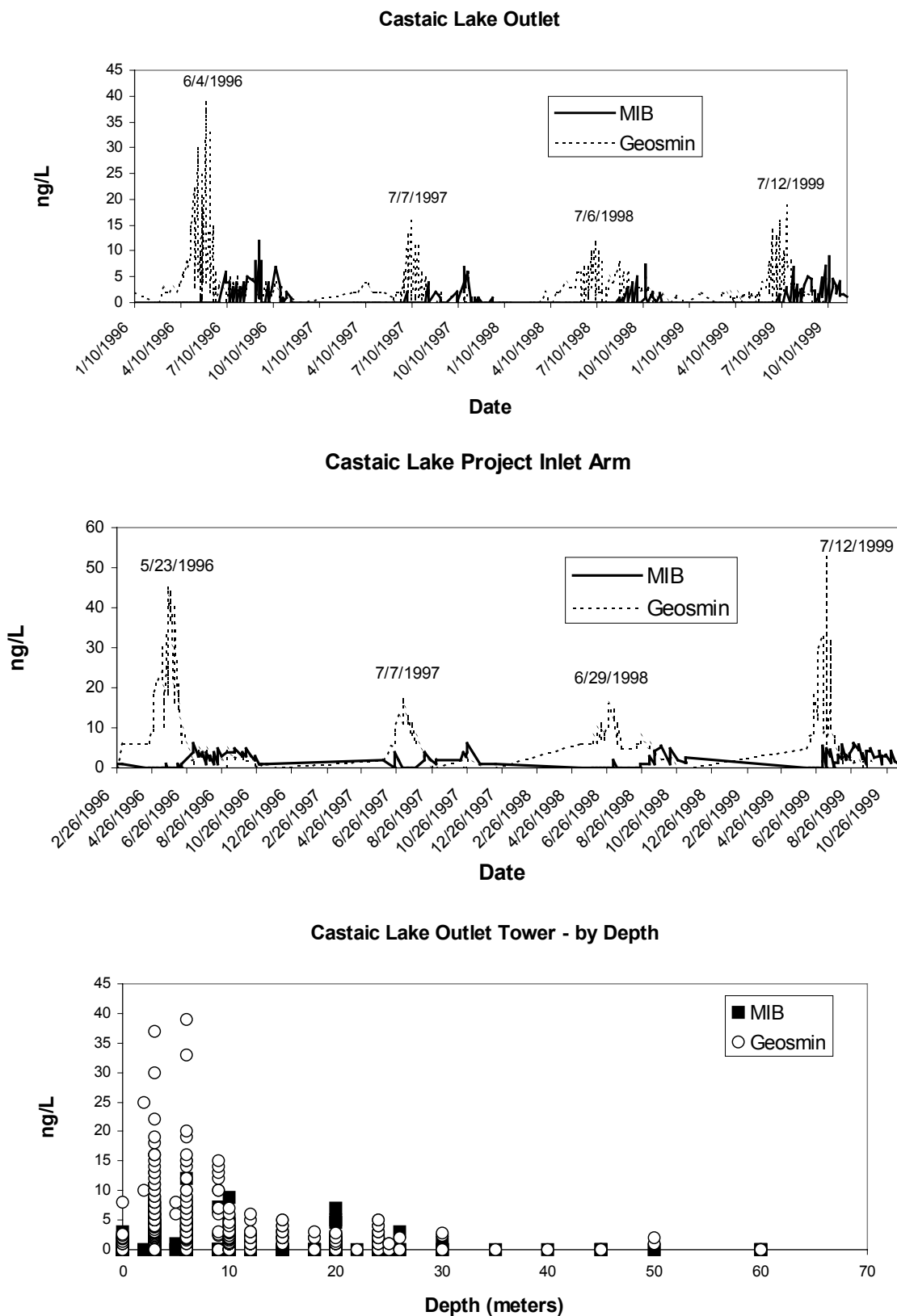
MIB and geosmin are organic compounds resulting from algal growth that impart undesirable

taste and odors to drinking water. While periods of excessive MIB and geosmin are associated with algal blooms in spring and fall, detectable levels of taste and odor affectors can occur in the Southern California reservoirs at any time of the year (Losee pers. comm. 2001). The taste and odor threshold for geosmin and MIB ranges from 5 to 10 ng/L.

MIB and geosmin are produced by algae, and in particular blue-green algae, near the surface of Castaic Lake. MIB and geosmin levels decline with increasing depth in Castaic Lake during peak growth season and during the winter. This temporal pattern is illustrated in Figure 7-14. Geosmin was detected in 78% of the surface samples (0 to 3 meters)

collected in Castaic Lake. The range was nondetect to 63 ng/L. When detected, the mean was 6.1 ng/L. MIB was detected in only 32% of the surface samples with a range of not detected (ND) to 10 ng/L. When detected, the mean MIB concentration was 1.07 ng/L. The highest values occurred between the months of May and October.

Managers use reservoir management practices such as selective depth withdrawal to minimize the amount of MIB and geosmin in lake outflow sent to the Jensen FP via the Foothill Feeder. The Jensen FP is discussed in detail under Section 7.2.2, Water Supply System.

Figure 7-14 MIB and Geosmin Levels, Castaic Lake Outlet, 1996 to 1999

7.2.4.2 Water Supply System

MWDSC Jensen Filtration Plant

MWDSC routinely monitors source (influent) and treated (finished) water quality to meet primary and secondary MCLs contained in Title 22 California Code of Regulations. Title 22 parameter categories for primary MCLs include inorganic chemicals (trace metals, nitrate/nitrite, asbestos), microbiological radioactivity, TTHMs, and organic chemicals. Secondary MCLs include, but are not limited to, iron, manganese, odor, turbidity, TDS, conductivity, chloride, and sulfate.

The main water quality concerns of MWDSC for treating SWP water are occasional high turbidities, DBP formation from TOC/bromide, and taste and odor problems associated with algal blooms. For the 1996 to 1999 period, finished water quality from the Jensen FP was well below all applicable primary and secondary MCLs for all regulated parameters. Source water quality was well below primary MCLs for inorganics, organics, and radionuclides. (Torobin pers. comm. 2000). Data were obtained from the MWDSC laboratory database for 1996 to 1999, summaries from annual reports, and their consumer confidence reports for this period.

Trace metals and organic compounds are discussed first because they are either detected at low levels or not routinely detected and are, therefore, not of concern. The main parameters of concern selected for further discussion are presented below after trace metals and organics.

Aluminum, arsenic, barium, and iron were the only trace metals detected in Jensen FP influent (molybdenum and strontium were also detected but have no MCLs). Barium was present below the 0.05 mg/L level reported above in the watershed water quality section, and aluminum averaged 0.035 mg/L, with 1 high value of 0.47 mg/L, which was still below the MCL of 1 mg/L. Iron was not

consistently detected and was always below 0.06 mg/L. Arsenic levels ranged from 0.0015 to 0.003 mg/L and averaged 0.002 mg/L, well below the current MCL of 0.05 mg/L. These values are also below the proposed MCL being evaluated for arsenic of 0.01 mg/L. The same trace metals were detected in Jensen FP finished water but at even lower levels.

Organic chemicals have many different analytical classes but in Title 22 are divided into 2 categories: volatile organic chemicals (VOCs) and nonvolatile synthetic organic chemicals (SOCs). VOCs include such compounds as benzene, MTBE, and trichloroethylene (TCE). SOCs include many of the organochlorine and organophosphate pesticides and other pesticides and herbicides. With the exception of MTBE, no VOCs, pesticides, herbicides, or other SOCs were detected at or above both the detection limits for purposes of reporting or laboratory detection limits in either source or finished water (Koch pers. comm. 2000, 2000a; Torobin pers. comm. 2000, 2001). MTBE was never detected in Jensen FP finished water.

The main drinking water parameters of concern in source and finished water as presented in watershed water quality section were selected for further discussion. These include in order: TDS, turbidity, nutrients, TOC (and D/DBPs), MTBE, and taste and odor. As shown in the following discussion of these parameters, the water quality of Jensen FP influent largely reflects that of Castaic Lake.

TOTAL DISSOLVED SOLIDS. Water quality data for TDS and sulfate in Jensen FP influent and finished waters and Castaic Lake are presented in Table 7-11. Sulfate was included with TDS to illustrate the connection with Pyramid Lake and Piru Creek. Chloride levels at these locations are very low and are not an issue.

Table 7-11 Comparison of TDS and Sulfate Concentrations (mg/L)

Parameter/Value	Castaic Lake	Jensen FP	
		Influent	Finished
TDS			
Range	266-406	278-392	302-371 ^a
Average	319	323	329 ^b
Sulfate			
Range	70-129	70-131	81-120 ^a
Average	97	97	98 ^b

^a Range of 1996 to 1999 annual averages only

^b Average of 1996 to 1999 annual average data

As shown in Table 7-11, both TDS and sulfate values are virtually unchanged in all 3 water sources. The highest TDS and sulfate values at all locations were in 1996, because of high natural inflows; and the lowest values were in 1998, because of the dilution effect of El Niño storms in Castaic Lake runoff, as discussed in the watershed section. The 10-year running average (1988 to 1997) for TDS in Jensen FP influent was 356 mg/L, while finished water was 362 mg/L (MWDSC 1998). All values were less than the secondary MCLs for TDS and sulfate of 500 and 250 mg/L, respectively.

TURBIDITY. High turbidities in the form of short-term spikes in the aqueduct, influent pipelines, and algal growth have caused occasional treatment problems at the Jensen FP. The effects on water treatment plants from high turbidity include increased chemical feed rates, excessive loading on solids handling facilities, lower filter run lengths, and higher than normal plant effluent (finished water) turbidities (MWDSC 2000).

Turbidities in Castaic Lake were low (as discussed in Section 7.2.4.1, Watershed, under Water Quality Summary) and ranged from 1 to 3 NTUs, averaging 1.6 NTU. Jensen FP influent turbidities averaged about the same at 1.4 NTU, but ranged from 0.3 to 9.5 NTUs, a much higher maximum value. The main problem associated with turbidity was high levels of algae in source waters that clog filtration systems. Finished waters were always well below the secondary MCL of 5 NTUs ranging from 0.04 to 0.06 NTU (1998 and 1999 data only - consumer confidence reports) and averaging 0.06 NTU.

NUTRIENTS. Nitrate levels (as NO_3) in Jensen FP influent were consistently higher than those of Castaic Lake. Jensen FP influent ranged from 1.2 to 2.3 mg/L and averaged 1.9 mg/L, while Castaic Lake values were <0.1 to 1.8 mg/L, with an average of 0.7 mg/L. Annual averages for both nitrate and nitrate+nitrite (as N) in finished waters were usually

the same and ranged from 0.4 to 0.5 mg/L, well below the MCL of 10 mg/L.

TOTAL ORGANIC CARBON AND ALKALINITY (DBP PRECURSORS). DBP precursors in SWP water such as TOC and bromide react with disinfectants at the Jensen FP to produce TTHMs and haloacetic acids (HAAs), which along with bromate are the primary DBPs of concern. Although MWDSC has not exceeded the current MCL for TTHMs, TOC and bromide levels in SWP water are too high to comply with the Stage 1 D/DBP Rule proposed MCL for TTHMs of 80 µg/L in the absence of additional treatment or other measures. Additionally, member agencies that receive finished water from the Jensen FP experience higher TTHM levels in their distribution systems because of the continued formation of TTHMs in the pipelines (MWDSC 2000).

Water quality data for TOC and alkalinity in Jensen FP influent and finished waters and Castaic Lake are presented in Table 7-12.

Castaic Lake TOC levels frequently exceeded the proposed drinking water protection standard of 3 mg/L at the export pumps at Banks, while Jensen FP influent exceeded it but less frequently. Castaic Lake TOC levels were somewhat higher than Jensen, with a much higher high-range value, while Jensen FP influent and finished water were very similar. It is not known why Castaic Lake TOC levels appear to be higher than Jensen FP influent, given the enclosed nature and relatively short distance of the Foothill Feeder pipeline. Alkalinities were very similar at all locations and were consistently within the 60 to 120 mg/L proposed in the D/DBP Rule for 25% TOC removal at TOC values from >2-4 mg/L. All TOC values in Jensen FP influent were below 4 mg/L.

Bromide levels in Castaic Lake ranged from 0.12 to 0.14 mg/L and averaged 0.13 mg/L. These values also exceed the proposed drinking water protection standard of 0.05 mg/L for bromide.

Table 7-12 Comparison of TOC and Alkalinity at Jensen FP (mg/L)

Parameter/Value	Castaic Lake	Jensen FP	
		Influent	Finished
TOC			
Range	2.5-7.7	2.1-3.3	2.5-2.9 ^a
Average	4.0	2.7	2.7 ^b
Alkalinity			
Range	84-114	85-106	81-120 ^a
Average	99	96	98 ^b

^a Range of 1996 to 1999 annual averages only.

^b Average of 1996 to 1999 annual average data.

TTHMs are monitored in Jensen FP finished water only. TTHM levels ranged from 39 to 67 µg/L in 1998 to 1999 and averaged 49 µg/L on an annual average basis. During 1997, TTHMs were always below 50 µg/L. In 1996, the annual average was 56 µg/L. Finished water quality always met the current MCL of 100 µg/L, but MWDSC will be challenged with the proposed MCL of 80 µg/L in the Stage 1 D/DBP Rule.

The practice of using chlorine for primary disinfection results in TTHMs in the Jensen FP service areas greater than the proposed MCL of 80 µg/L. In addition, the Stage 1 D/DBP Rule will require enhanced coagulation removal of TOC, unless certain exceptions are met (25% TOC removal from >2-4 mg/L and alkalinity of 60 to 120 mg/L). MWDSC has decided to convert the Jensen FP from chlorination to ozonation for primary disinfection as the most effective solution to comply with Stage 1 and future Stage 2 requirements of the D/DBP Rule. The use of ozone and chloramines will reduce TTHMs to less than 40 µg/L, which will allow MWDSC to qualify for an exception to the enhanced TOC treatment component of the rule. However, the high TOC and bromide levels will still present treatment challenges. High TOC results in a higher ozone demand, which results in a higher level of ozone byproducts, and the conversion of TOC to assimilable organic carbon. The assimilable organic carbon can result in the growth of biofilm in the distribution system. MWDSC plans to employ biological filtration to reduce this carbon type.

Although ozone disinfection will help reduce the levels of TTHMs in finished water, ozone also reacts with bromide in source waters to produce bromate, considered a human carcinogen by the California Office of Environmental Health Hazard Assessment and a DBP regulated in the D/DBP Rule. Because of the relatively high bromide levels in SWP water, bromate levels typically formed during ozonation will exceed the Stage 1 bromate MCL of 10 µg/L. MWDSC plans to control the amount of bromate formed in the ozonation process by lowering the pH to 7.0 or lower using sulfuric acid addition. Higher bromide concentrations will require pH reduction to 6.0. Further, if the future Stage 2 D/DBP Rule lowers the proposed bromate MCL to 5 µg/L, the frequency of pH adjustments would dramatically increase (MWDSC 2000)

MTBE. The MTBE concentrations in surface samples near the outlet tower at Castaic Lake were high and ranged from 1 to 29 µg/L with an overall mean from both MWDSC and DWR samples of 8.7 µg/L. MTBE concentrations in samples collected

lower in the reservoir ranged from 3.3 to 16.0 µg/L with a mean of 6.6 µg/L. At the lowest portion of Castaic Lake sampled (the hypolimnion), MTBE was only detected in 4 of the 8 DWR samples and ranged from 2 to 4 µg/L with a mean of 1.3 µg/L.

MTBE levels in Jensen FP influent were generally lower and ranged from not-detected (detection limit 0.5 µg/L) to 1.2 µg/L. This is probably explained by a combination of the lower levels of MTBE in water being withdrawn at the outlet tower from greater depths and loss in the Foothill Feeder. These levels and those in the lowest portion of Castaic Lake were well below the MCL of 13 µg/L. MTBE was never detected in Jensen FP finished water.

TASTE AND ODOR. Jensen FP influent had much lower levels of MIB and geosmin than surface values in Castaic Lake. Geosmin was detected in 8% of 173 samples collected at Jensen FP. The range was ND to 6 ng/L. When detected, the mean geosmin concentration was 2.1 ng/L. MIB was detected in 2.4% of the samples with a range of ND to 2 ng/L. Of the samples where MIB was detected, the mean was 1.2 ng/L.

MIB and geosmin have extremely low taste and odor thresholds. Geosmin has an odor threshold of only 5 to 10 ng/L. Geosmin values were above the threshold level on 1 occasion (that is, 6 ng/L). MWDSC has developed a flavor profile analysis method for taste and odor in finished water that accurately detects odor occurrences.

CLWA Rio Vista Water Treatment Plant

The CLWA treatment plant uses 100% SWP water, and the influent is received at the same location as MWDSC, just with a shorter pipeline. Therefore, CLWA is subject to the same source water quality conditions as MWDSC. The CLWA water quality concerns are the same as those described above for MWDSC. The major concern is high levels of DBP precursors TOC and bromide (CLWA 2000a). They are also concerned about high turbidities associated with local watershed erosion conditions. CLWA did not report a major concern with taste and odor issues for this period. All Title 22 parameters were below applicable MCLs (McClean pers comm. 2000a, 2000b).

Similar to MWDSC, CLWA has chosen to adopt ozonation as the best solution to meet the D/DBP Rule requirements. The CLWA treatment plant processes include preozonation, contact clarification (a special process replacing conventional flocculation/sedimentation that biologically reduces DBP precursors), filtration, and primary disinfection by ozone.

Pathogens

Pathogen issues related to Castaic Lake are discussed in Chapter 12 for the Jensen FP.

7.2.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

The significant contaminant sources and major water quality concerns at Castaic Lake are related to both SWP source water and watershed activities. The main concerns associated with source water quality are DBP precursors (for example, TOC and bromide), taste and odor associated with algal growth in the reservoir, and turbidity caused by SWP inflow spikes and algal growth. The main water quality concerns associated with watershed activities include pathogens and MTBE from recreation, pathogens and erosion from animal populations, and TDS in natural inflows.

TOC and bromide do not appear to be significantly changed by watershed activities at Castaic Lake. The major contributor of these parameters is the Delta via the California Aqueduct at Check 41, which can also be a source of turbidity spikes. Castaic Lake and Jensen FP influent TOC levels exceeded the target drinking water protection standard of 3 mg/L, although Jensen FP was never above 4 mg/L. Bromide levels also exceeded the target drinking water protection standard of 0.05 mg/L. The MCLs for these parameters are currently being met, but high levels of DBPs in Delta and aqueduct water present challenges meeting Stage 1 D/DBP Rule limits for TTHMs and bromate.

Eutrophication of the lake caused by nutrient-loading from source waters, results in increased lake turbidity and production of MIB and geosmin, 2 compounds causing taste and odor problems in water supplies. Turbidity in delivery pipelines from Castaic Lake is also affected by sediment resuspension when contractors significantly and abruptly increase their flows. Nutrient levels in Castaic Lake were lower than Pyramid Lake and SWP inflows, and there was no evidence that watershed activities significantly contributed to existing nutrient loads. Use of copper sulfate for algae control can also be a source of copper but is not a concern for drinking water supplies at this time.

Recreation is an important contaminant source and water quality concern within the Castaic Lake watershed. The water quality problems associated with recreational activities at Castaic Lake are the contribution of pathogens, release of MTBE from motorized watercraft, and turbidity because of erosion in camping and shoreline areas, hiking, biking, etc. MTBE, although higher in the lake, was always below the MCL in Jensen FP influent but still

poses a potential threat to drinking water quality. Body-contact recreation is considered a significant, although as yet unquantified, potential pathogen source. Also of concern for release of pathogens are the 3 floating toilets (potential spills, leaks) and incidental waste releases from boats. In addition to the potential to cause disease in water recreationists, large enough concentrations of pathogens might also overwhelm the Jensen FP, especially under higher turbidities, and inhibit the required removal levels for pathogens under the Interim Enhanced Surface Water Treatment Rule (IESWTR).

Both grazing and wild animals in the watershed represent a potential pathogen source. However, the contributions from animal populations are impossible to assess with existing data. Erosion caused by grazing animals, especially in shoreline areas, results in increased turbidity in the lake. Grazing has been a problem in the watershed and is exacerbated by poor maintenance of fencing, which results in shoreline erosion and erosion in other areas as well. Fire is not a direct contaminant source but can result in increased erosion and turbidity, especially in grazing areas.

TDS and sulfate concentrations in Castaic Lake and Jensen FP influent are below the secondary MCL of 500 mg/L. However, it appears that the levels of these parameters are elevated relative to SWP source water because of inflows from Piru Creek in the Pyramid Lake watershed.

Wastewater treatment plant effluent is considered a low threat because there are only 2 small WWTPs in the watershed and they do not discharge effluent to a receiving stream. There were no spills or problems with the extensive sewage collection system and 5 pump stations, but the potential exists and could be significant if spills occurred. The contaminants of concern are pathogens, DBPs, and nutrients. Septic systems also present an unknown but significant potential source of pathogens and nitrate in the Elizabeth Lake area, Castaic Powerplant, and the rustic boat-in sites.

Leaks and spills of hydraulic oil used at SWP facilities such as power plants can be a source of organic contaminants such as petroleum hydrocarbons.

7.2.6 WATERSHED MANAGEMENT PRACTICES

There are several agencies with management authority in the Castaic Lake watershed. However, an overall watershed assessment/management program is not present, and no specific best management practices (BMPs) are in place or proposed for implementation. DWR constructed the reservoir and is primarily responsible for its

operation. The Los Angeles County Department of Parks and Recreation manages the Castaic Lake SRA and controls recreation activities within the watershed. Recreational boating is also regulated through the DBW. Recreation presents the largest watershed management issue at Castaic Lake, and activities often can be significant potential sources of contamination. Strategies to address and mitigate impacts on drinking water quality are being discussed in a water quality and recreation focus group—DWR, both California and county departments of parks and recreation, and other involved agency staff.

The regional water quality control board regulates through NPDES permits, and unauthorized discharges such as spills or overflows are prohibited. The Los Angeles County Department of Public Works is regulated to prevent spills to surface waters from the sewage collection system. The Los Angeles County Health Department oversees this area, as well as septic system issues.

The USDA Forest Service manages much of the land used for grazing in the watershed, has guidelines in grazing leases, and surveys areas to maintain residual mulch on grazing land to protect the soil base. Its role and powers are described in Section 7.1, Pyramid Lake. The State Water Resources Control Board (SWRCB) Non-point Source program has guidelines for water quality management in rangeland areas. Livestock grazing management practices to protect water quality include exclusion by fencing or other barriers, attraction, culling, and changing herd structure or distribution and grazing systems or both (George 1996). Implementation of these practices around shoreline areas would reduce water quality impacts associated with grazing by protecting bank structure, soils, and vegetation in these areas.

The high TDS and sulfate from natural sources in Piru Creek should be evaluated to verify previous findings, identify the sources and mechanisms involved, and determine if it could have a significant effect on water quality.

DWR is responsible for managing the physical facilities for the SWP such as power plants, etc. Because leaks and spills from equipment are a potential contaminant source, vegetable oils or water have been recommended as possible replacements.

7.3 SILVERWOOD LAKE

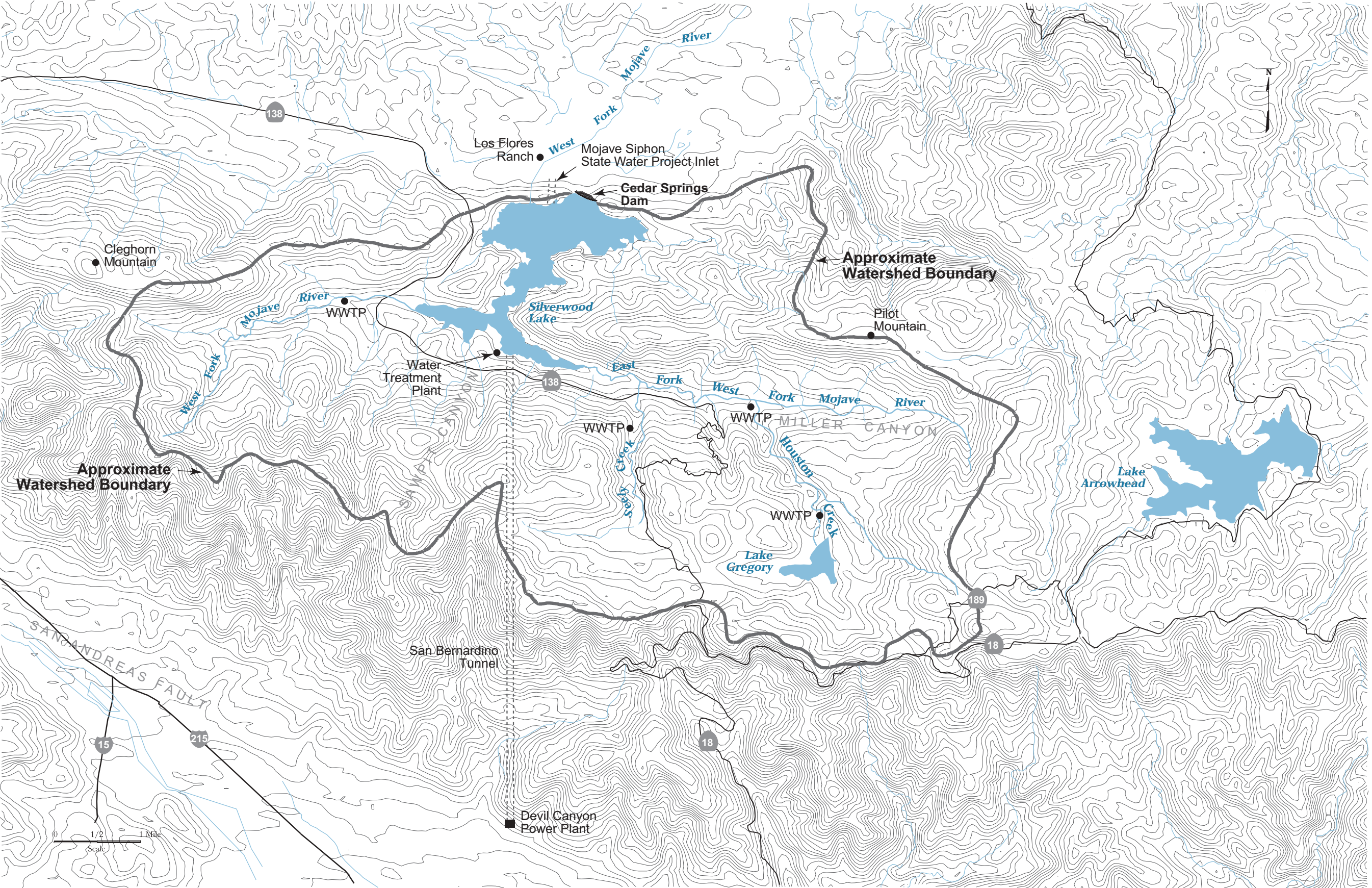
7.3.1 WATERSHED DESCRIPTION

Silverwood Lake is formed by Cedar Springs Dam on the west fork of the Mojave River. It is in the San Bernardino National Forest and approximately 30 highway miles north of the city of San Bernardino. At 3,355 feet, Silverwood is the highest of the 4 Southern California SWP reservoirs but has one of the smallest watershed at 29 square miles. Silverwood Lake is a multipurpose facility, providing emergency and regulatory storage as well as domestic water for the surrounding mountain and desert communities. Silverwood Lake also provides recreational opportunities and fish and wildlife habitat. It is the 1st reservoir on the East Branch of the California Aqueduct. SWP water flows into the lake through the Mojave Siphon Powerplant and flows out of the lake into the San Bernardino Tunnel, which leads to the Devil Canyon Powerplant (Figure 7-15). These facilities are discussed under Section 7.3.2.1, Description of Aqueduct/SWP Facilities.

7.3.1.1 Land Use

The 29 square mile watershed is composed mainly of San Bernardino National Forest land. The Silverwood Lake SRA occupies the area immediately surrounding the lake. California State Parks operates the SRA, which offers a variety of body contact and nonbody-contact recreational activities. Most of the recreational amenities are along the south shore of the lake. There is some residential development along Cleghorn (also known as the West Fork Mojave River) and Sawpit creeks in the southern portion of the watershed. There is a substantial amount of development surrounding Lake Gregory, a lake to the south that drains into Silverwood Lake.

Figure 7-15 Silverwood Lake Watershed Area



7.3.1.2 Geology and Soils

Soils primarily consist of sediments from the parent rock of the surrounding area. The USDA has not conducted a detailed soil survey in this region of the county. Soils north of Cedar Springs Dam are described as loamy and sandy sediments (USDA 1971).

The central portion of the watershed contains granite, quartz monzonite, granodiorite, and quartz diorite. The southern portion of the watershed contains a complex of igneous and metamorphic rocks, consisting mostly of gneisses and schists. In the northern portion of the watershed, Highway 138 bisects a region of alluvium, lake, playa, and terrace deposits, and a region of loosely consolidated sandstone, shale, and gravel deposits. The watershed contains well-located fault traces that occur in the batholithic rocks as well as in the granites.

Cedar Springs Dam lies in a seismically active region, approximately 10 miles north of the San Andreas Fault (Figure 7-15).

7.3.1.3 Vegetation and Wildlife

Climate and weather pattern, along with the watershed's proximity to the ocean, play a role in determining its vegetation types. The lower elevations surrounding the northern portion of the lake are predominately covered by desert chaparral, which is dominated by scrub oak and manzanita. The southern portion of the lake is also surrounded by desert chaparral except along the 2 branches of the Mojave River, which flow seasonally and support oaks and sycamores (DWR 1996). The higher elevations are populated with Ponderosa pines, incense cedar, Douglas fir, and black oaks (DWR 1991).

There is a substantial but unknown wildlife population in the largely undeveloped watershed. Avian species observed in the watershed include mountain chickadees, acorn woodpeckers, Stellar's jays, thrashers, wrentits, and quail. Mammalian species include Mule Deer, mountain lions, bobcats, gray fox, and coyotes as well as squirrels and white-

footed mice. Bald eagles have been observed nesting around the lake (DWR 1991).

7.3.1.4 Hydrology

Silverwood Lake is in the rain shadow of the San Bernardino Mountains, which have a varying effect on the climate and weather of the watershed (Schoenherr 1992). The lake has 3 main sources of inflow in the 29 square-mile watershed. They are SWP inflows and natural inflows from the West Fork Mojave River (or Cleghorn Creek) and from the East Fork West Fork Mojave River (or Miller Canyon Creek) (Figure 7-15). Cleghorn Creek drains a relatively undeveloped portion of the watershed descending from Cleghorn Mountain. Miller Canyon Creek collects water from the southeastern portion of the watershed, as well as Seely and Houston creeks. Houston Creek originates at Lake Gregory, approximately 5 miles upstream of Silverwood Lake. Lake Gregory is a small lake in the southern portion of the watershed. Its high elevation means that Lake Gregory collects snow runoff in the spring. Water is kept in the lake through the summer months and released to Houston Creek in September. Houston Creek is tributary to Miller Canyon Creek and Silverwood Lake.

In 1996 and 1997, natural inflows totaled 11,714 and 8,890 acre-feet, or about 2% of the total inflow (Table 7-13). The El Niño storms of 1998 led to higher-than-average natural runoff. In 1998, the natural inflow made up 10% of the total lake inflow.

Table 7-13 Annual Natural Inflows to Silverwood Lake (acre-feet)

1996	1997	1998	1999
11,714	8,890	41,685 ^a	2,291

Source: DWR Division of O&M, SWP Operations Data, 1996 to 1999

^a13,948 acre-feet total in Feb 1998 during El Niño storms; 9,177 in May.

However, SWP inflows are substantially greater than the natural runoff (Table 7-14).

Table 7-14 SWP Inflow/Outflow for East Branch and Silverwood Lake (acre-feet)

	1996	1997	1998	1999
East Branch Outflow	490,254	603,691	439,565	607,066
Silverwood Lake:				
Inflow	398,250	495,507	352,561	499,644
Outflow	440,661	443,005	356,851	503,735

Source: DWR Division of O&M, SWP Operations Data 1996 to 1999

Outflow from the lake includes releases to the Mojave River below Cedar Springs Dam and releases to the San Bernardino Tunnel, which supplies the Devil Canyon Powerplant and the rest of the East Branch of the California Aqueduct. The SWP inflow comes from the north side of the lake, and the major outflow is at the southern side of the lake. This creates a north-to-south flow regime. SWP water has an estimated residence time of only 20 to 30 days in the lake; therefore, thermal stratification does not always occur in the lake (DWR 1996a).

7.3.2 WATER SUPPLY SYSTEM

7.3.2.1 Description of Aqueduct/SWP Facilities

Cedar Springs Dam, constructed on the West Fork Mojave River and completed in 1971, created Silverwood Lake at mile 405.6 of the East Branch of the California Aqueduct. Silverwood Lake provides regulatory and emergency storage, recreation, wildlife habitat, and insures a continuous flow through the Devil Canyon Powerplant. The reservoir has a storage capacity of about 74,970 acre-feet, a surface area of about 980 acres, and a shoreline of approximately 13 miles (Brown and Caldwell 1990). Silverwood Lake has a maximum depth of 166 feet and an average depth of 77 feet. SWP water flows into the lake via the Mojave Siphon Powerplant from

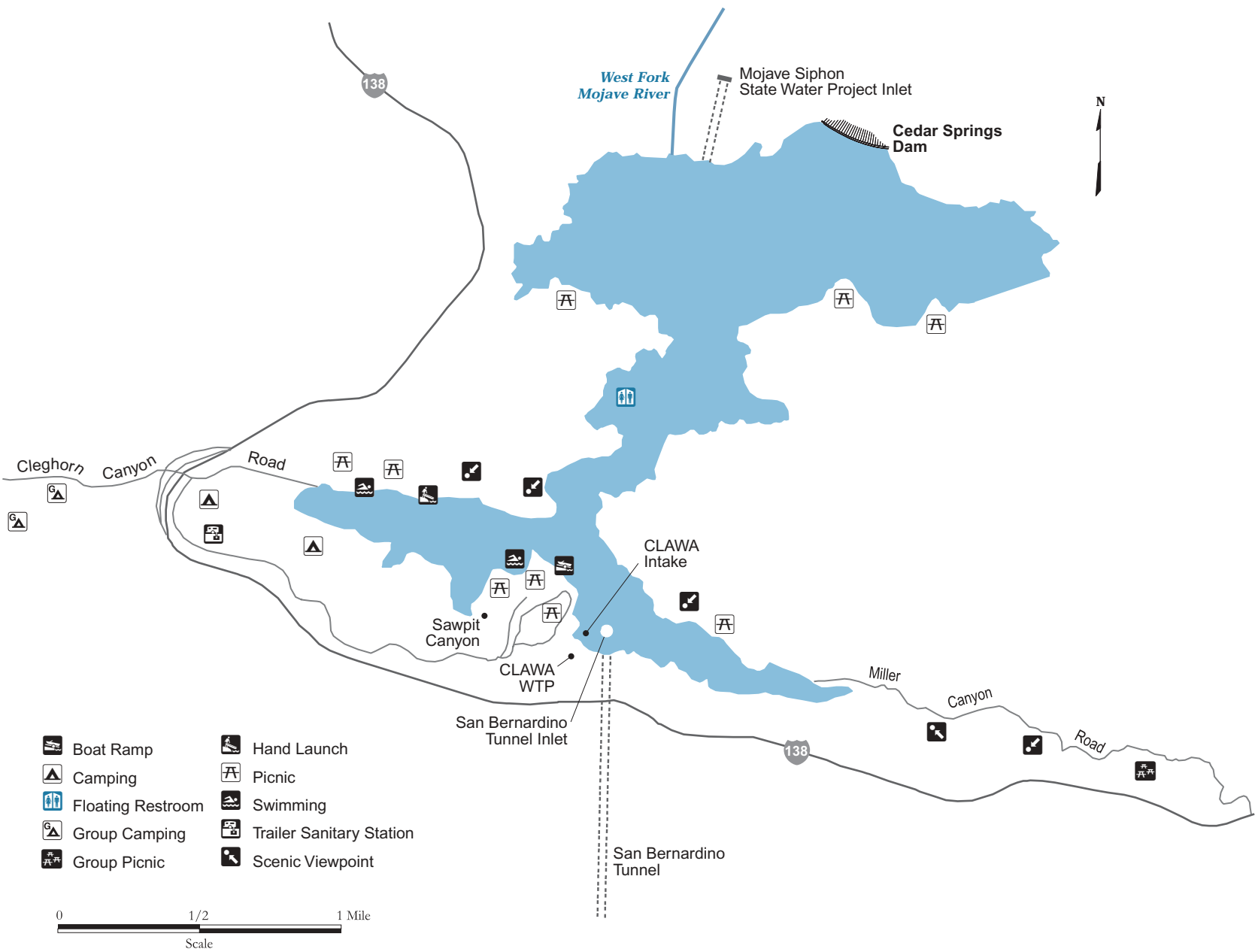
the East Branch of the California Aqueduct. A bypass tunnel can carry the water around the power plant, if necessary. The lake inlet is on the northern edge of the lake, west of Cedar Springs Dam.

The stream release point is on the north side of the lake, near and downstream of the dam. SWP water is also discharged from Silverwood Lake through the San Bernardino Tunnel. The tunnel inlet is along the southern shore of Silverwood Lake near the Sawpit Canyon area (Figure 7-16). The San Bernardino Tunnel flows 3.8 miles to the Devil Canyon Powerplant. From Devil Canyon, SWP water enters the Santa Ana Pipeline, which conveys water with several delivery turnouts along the way to Lake Perris, the terminus of the East Branch of the California Aqueduct.

Silverwood Lake is an important link in the East Branch of the California Aqueduct because SWP water flows out from the lake through the San Bernardino Tunnel and, therefore, contamination from the watershed could affect water quality down the East Branch.

The only change in SWP facilities at Silverwood Lake from 1996 to 1999 was the construction of a new intake tower to the San Bernardino Tunnel. The intake tower was reconstructed for seismic stability. This construction project is discussed under Section 7.3.3.9, Land Use Changes.

Figure 7-16 Silverwood Lake



7.3.2.2 Description of Agencies Using SWP Water

There are 5 agencies contracting for deliveries from Silverwood Lake between miles 407.7, 412.88, and 425.46. They are MWDSC, San Gabriel Valley Municipal Water District (SGVMWD), San Bernardino Valley Municipal Water District (SBVMWD), San Geronio Pass Water Agency (SGPWA), and the Crestline-Lake Arrowhead Water Agency (CLAWA).

MWDSC, the single largest entitlement holder of the SWP, is a consortium of 27 member agencies and more than 150 subagencies that provide drinking water to nearly 17 million people in parts of Los Angeles, Orange, San Diego, Riverside, San Bernardino, and Ventura counties. MWDSC has an annual SWP entitlement of 2,011,500 acre-feet, 556,500 of that from the East Branch (Lischeske pers. comm. 2000). MWDSC receives its East Branch deliveries from a turnout at the Devil Canyon afterbay at mile 412.88 of the East Branch of the California Aqueduct. Water stored in Silverwood Lake is delivered to MWDSC's Henry J. Mills FP via Devil Canyon.

The Mills FP is in Riverside at an elevation of 1,650 feet. Treated water flows by gravity to the service areas of Eastern Municipal Water District and Western Municipal Water District of western Riverside County and the Moreno Valley. Specific communities served include Bedford Heights, El Sobrante, Rancho Cucamonga, Sun City, and Upland. The Mills FP has a maximum treatment capacity of 326 mgd. MWDSC is in the process of retrofitting the plant to use ozonation for disinfection instead of the current chlorination process (MWDSC 1998).

CLAWA delivers treated water to wholesale and residential customers in the San Bernardino Mountains from Crestline to Green Valley Lake as well as the Silverwood Lake SRA. CLAWA has an annual entitlement of 5,800 acre-feet and takes its deliveries directly from Silverwood Lake from its own outlet tower near aqueduct mile 407.7, which was constructed along the south shore of the lake near the outlet tower for the San Bernardino Tunnel inlet. CLAWA's treatment plant is on the south shore of the lake adjacent to its outlet tower (Figure 7-16). The CLAWA treatment plant operates at a capacity of 3 mgd. In 1999, CLAWA constructed additional holding tanks to upgrade the treatment process. This construction project is discussed in Section 7.3.3.9, Land Use Changes.

SBVMWD is the largest East Branch contractor of SWP water after MWDSC and has a maximum annual SWP entitlement of 102,600 acre-feet. SBVMWD takes deliveries from the Devil Canyon

afterbay as well as from 2 turnouts along the Santa Ana Pipeline.

SGVMWD has a maximum annual SWP entitlement of 28,800 acre-feet and receives its deliveries from a turnout at the Devil Canyon afterbay. The SGVMWD conveys SWP water through its distribution system downstream to 6 or 7 groundwater recharge facilities. The recharge facilities are managed by the Los Angeles County Department of Public Works, which owns and operates the spreading grounds. Individual cities and municipalities such as Azusa, Irwindale, Covina, and Glendora pump and treat groundwater for their service areas (Kasamoto pers. comm. 2000).

SGPWA has a maximum annual SWP entitlement of 17,300 acre-feet and receives deliveries from a turnout at the end of the San Bernardino Tunnel at aqueduct mile 411.46, before the Devil Canyon Powerplant.

7.3.3 POTENTIAL CONTAMINANT SOURCES

7.3.3.1 Recreation

The Silverwood Lake SRA provides a number of body contact and nonbody-contact recreational activities. Body contact activities include boating, water-skiing, and swimming in selected areas. Nonbody-contact activities include fishing, picnicking, camping, hiking, and bicycling. The major water quality problems associated with recreation in the watershed are the following:

- Contribution of feces from body contact recreation such as swimming,
- Fuel spills and exhaust releases from motorized watercraft,
- Spills or leakage from restrooms or wastewater collection systems, and
- Erosion and increased turbidity associated with hiking, horseback riding, or camping, particularly if activities are conducted off established areas and trails.

The Sawpit Canyon area on the south side of the lake includes boat launching ramps and slips, a snack bar, boat rentals, a fishing supply store, a swimming beach, and picnic grounds. The area also includes parking lots and fuel storage facilities. Recreational facilities are illustrated in Figure 7-16.

The Cleghorn Cove area on the southwestern arm of the lake also includes recreational facilities: parking, picnic grounds, 2 campgrounds and a swimming beach. There is a hand launch ramp for nonmotorized boats. The Cleghorn area offers a trailer sanitary station and 2 group camps along Cleghorn Creek; all are less than a mile from the lake.

Table 7-15 Recreational Facilities at Silverwood Lake

	Miller Canyon	Serrano Beach	Sawpit Canyon	Cleghorn
Boat Ramp (Lanes)			6	2
Snack Bar			2	1
Picnic Sites		3	260	88
Group Picnic Sites	3			
Campsites			136	
Group Campsites	3			3
Swimming Beach			1	1
Sanitary Facilities	7	1	16	7
Trailer Sanitation Station			1	
Fish Cleaning Stations			1	1
Parking Spaces	110		878	290

Source: DWR 1991

Notes: Sawpit area includes Mesa Campground.

Cleghorn area includes West Fork campgrounds.

Parking spaces include trailer parking but do not include unmarked spaces around the lake.

Other recreational facilities are around the lake. A summary of the numbers and types of facilities is provided in Table 7-15. The Miller Canyon area includes picnic and group picnic grounds and several scenic viewpoints. Boat-in picnic grounds are around the northern part of the lake. There is also parking at the dam viewpoint on the northern edge of the lake. A 14-mile bicycle trail and a 6-mile hiking trail traverse the southern portion of the lake.

Recreational use for the 1996 to 1999 period is presented in Table 7-16. Recreational use has declined since its peak in 1987 of 769,200 recreation days. This decline has been attributed to factors such as poor local economic conditions, increased park fees, changes in fish stocking policies, and restrictions on the types of recreational activities allowed (DWR 1995). Silverwood Lake experienced less recreational use during the 1996 to 1999 period than Castaic Lake or Lake Perris. Recreational use follows a seasonal pattern, with most of the use being between April and September. The lower use figures for 1996 are attributed to the construction of a new inlet tower for the San Bernardino Tunnel that required lowering the reservoir water level.

Table 7-16 Recreational Use at Silverwood Lake (Recreation Days)

1996	1997	1998	1999
237,000	315,400	374,900	330,000

Source: Thrapp pers. comm. 2000a

A total of 26,427 boats were launched at Silverwood Lake during the 1997/98 fiscal year, the last year for which a complete data set was available (Cermak pers. comm. 2000). Eighty-eight percent of those boats were launched between April and September.

Wastewater collection systems for recreation facilities exist at the Cedar Springs Dam, the Sawpit Canyon recreational area, and the Cleghorn Cove area. At Cedar Springs Dam, septic systems and a leach field are used for sanitary waste disposal. The restrooms service site-support buildings. At Sawpit Canyon, wastewater flows by gravity to a lift station where a force main conveys the wastewater to the Crestline Sanitation District's Cleghorn WWTP. The plant is along Cleghorn Creek, upstream of Silverwood Lake (Figure 7-15). There are at least 4 lift stations along this force main. Several of these pump stations have experienced failures and overflowed in the past (Brown and Caldwell 1990). One lift station is within 100 feet of the reservoir. Two are approximately 250 feet from the lake, and the 4th is approximately 1,000 feet from the reservoir. Each lift station is equipped with alarms, spare motors and pumps, and an emergency generator. Wastewater from the Cleghorn Cove area is stored in an underground tank until it is pumped to the force main that connects the Sawpit Canyon area with the Cleghorn WWTP.

Other areas around the lake use chemical toilets for sanitary waste, which are serviced by truck. There is 1 floating toilet on the lake, which is serviced by a septic tank pump truck mounted on a

barge. Table 7-15 also lists the number of sanitary facilities by area. In December 1999, the floating toilet capsized releasing a small amount of waste into the reservoir. The incident happened sometime overnight, and the toilet was upright by the following afternoon. The holding tank had recently been emptied, which limited the spill to an estimated 10 gallons. The solids remained in the tank. The incident occurred about 1 mile from the lake outlet. Samples were collected and analyzed for pathogens at the spill site, midway between the spill site and the outlet, at the outlet, and at MWDSC's turnout at the Devil Canyon afterbay. Results showed no detectable levels of contamination (MWDSC 2000).

Much of the watershed area that lies outside of the SRA is national forest land. Allowed recreational activities include hiking, horseback riding, and off-highway vehicle (OHV) riding. These activities may cause erosion and contribute to increased turbidity and TDS levels in creeks tributary to Silverwood Lake. The USDA Forest Service is working with OHV user groups to minimize the erosion caused by OHV use (USDA 2000). A portion of the Pacific Crest Trail runs through the watershed, skirting the west and north sides of the lake.

Additional recreation area changes included minor shoreline improvements such as planting of new turf and trees in April 2000. The DBW provided funding for expansion of the Sawpit Canyon launch ramp from 6 lanes to 7, to overlay it with concrete, and to reconstruct the shoreline. The launch ramp at Cleghorn Canyon was lengthened (DWR 1997a). Additional recreational facilities exist at Lake Gregory, a smaller but fully recreational lake in the upper watershed. Lake Gregory overflows to Houston Creek and eventually reaches Silverwood Lake (Brown and Caldwell 1990).

7.3.3.2 Wastewater Treatment/Facilities

Treatment Plant Effluent Discharges

There are 4 WWTPs within the watershed. The Crestline Sanitation District operates 3 of them: Houston Creek, Seely, and Cleghorn WWTPs. Their service area includes the city of Crestline and neighboring communities around Lake Gregory. Crestline Sanitation District also collects waste from the Silverwood SRA. The 4th WWTP is at the Pilot Rock Camp and is operated by the California Department of Forestry. All 4 WWTPs are within the watershed, above Silverwood Lake (Figure 7-15).

The Houston Creek WWTP is along Houston Creek between Lake Gregory and the confluence of Houston Creek and the East Fork West Fork Mojave River. The Seely WWTP is along Seely Creek, and the Cleghorn WWTP is along the West Fork Mojave

River upstream from Silverwood Lake. The 4th WWTP is at the Pilot Rock Conservation Camp, a minimum-security correctional facility that houses firefighting personnel on a seasonal basis. The Pilot Rock WWTP is a small package plant that provides secondary treatment of wastes and has a maximum capacity of 0.01 mgd.

The Houston Creek, Seely, and Cleghorn plants were upgraded during the 1996 to 1999 period. A 2.5 million-gallon emergency storage reservoir was installed at the Houston Creek plant in July 1998. A second emergency storage reservoir is planned for the Seely plant. This reservoir is in the final planning stages with funding scheduled for the 1999/2000 fiscal year. These emergency storage reservoirs will increase the reliability of the treatment plants and allow a temporary interruption in effluent flow for maintenance of the outfall system (Whalen pers. comm. 2000). Improvements to the Cleghorn plant included the coating of all concrete surfaces with a plastic polymer, replacement of bearings in 1 of the motors, and reconstruction of walkways.

All 4 WWTPs provide secondary treatment and disinfection of wastes. Their combined dry weather flow averages 0.8 mgd (DWR 1996). The treated effluent is transported to the Las Flores Ranch just north of the dam and outside the watershed. There it is used for pasture irrigation or distributed to percolation ponds. Waste Discharge Requirements imposed by the Regional Water Quality Control Board regulate treated effluent. Waste discharged to the Las Flores Ranch is regulated for BOD, pH, dissolved oxygen, and other conventional wastewater parameters. There were no reported constituent violations in the district's final effluent from 1996 to 1999 (Whalen pers. comm. 2000).

The volume of wastewater treated annually by the Crestline Sanitation District has increased during the period of this study from 292.35 million gallons in 1996 to 408.26 million gallons in 1998. Crestline Sanitation District did not have any unauthorized wastewater releases caused by high flow conditions posed by El Niño storms of 1998 (Whalen pers. comm. 2000).

The Lake Arrowhead Sanitation District (LASD) operates wastewater collection and treatment facilities in an area adjacent to the Silverwood Lake watershed. The service area and the drainage area of this district lie entirely outside the Silverwood Lake watershed, as opposed to what was reported in the *Sanitary Survey Update 1996*, which included the facilities in the watershed. Drainage from the service area flows north, away from Silverwood Lake (Nelson pers. comm. 1999). Wastewater spills in the LASD service area would not impact the Silverwood Lake watershed.

Storage, Transport, and Disposal

The wastewater collection facilities consist of 4 WWTPs and their associated distribution pipes. Pilot Rock WWTP effluent is discharged to an outfall line owned and maintained by the Crestline Sanitation District. Sludge from the Pilot Rock Plant is transported by truck to the Houston Creek Plant where it is dewatered and disposed of, along with sludge from the Houston Creek Plant, outside of the watershed (Whalen pers. comm. 2000). Wastewater from the Silverwood SRA is transported to the Cleghorn WWTP via a pressurized force main. All 4 WWTPs are connected to a single outfall pipe, which closely parallels Highway 138 as it wraps around the western edge of Silverwood Lake. Treated effluent is transported through this pipe to the Las Flores Ranch, which is outside the watershed.

No incidents that resulted in the release of wastewater to surface waters in the watershed during the period 1996 to 1999 were reported (Whalen pers. comm. 2000). In 1993 a construction accident led to the release of 11 million gallons of treated sewage into the Mojave River, below Cedar Springs Dam. This incident prompted the Crestline Sanitation District to install low flow alarms and a holding vault. Although no wastewater releases were reported during the period of this study, the location of the treatment facilities on creeks tributary to Silverwood Lake presents the potential for contamination.

Septic Systems

Many of the smaller developments and individual residences in the watershed are on septic systems. Very little information is available on the effect septic systems may have on groundwater and surface water quality. The Regional Water Quality Control Board and the San Bernardino County Department of Environmental Health Services have investigated the septic systems of a community called Cedar Pines Park. Cedar Pines Park is in the southern portion of the watershed between Sawpit Creek and Lake Gregory, about a half mile from Sawpit Creek. The control board sampled monitoring wells on the site to determine the effect that the septic systems had on groundwater quality. None of its sampling results showed nitrate levels in excess of applicable drinking water standards. The highest nitrate concentrations (23, 25, and 26 mg/L as NO₃), which were below the MCL of 45 mg/L, were observed in the same well. Environmental health services concluded there were no overall immediate problems with nitrates in Crestline area groundwater (Trujillo pers. comm. 1989).

7.3.3.3 Urban Runoff

Runoff from paved areas is a significant potential contaminant source and may contain metals, organic compounds and petroleum hydrocarbons, pathogens, and suspended solids. The Silverwood SRA has more than 1,000 paved parking spaces as well as paved roads that could contribute runoff. Runoff from Highway 138 and urban development in the southern portion of the watershed may contribute significant amounts of runoff containing the parameters of concern mentioned.

Paved areas of the CLAWA water treatment plant also contribute storm water runoff. The CLAWA plant is adjacent to the lake near the San Bernardino Tunnel intake tower. Personnel working in the Silverwood Lake area have observed muddy water and siltation in Sawpit Creek and drainage near the CLAWA water treatment plant (Rubio pers. comm. 1999). These discharges have been observed over the last 2 years.

The Cedar Pines Park Water Company serves a small community in the southern portion of the watershed near Lake Gregory. In 1997, Cedar Pines Park Water Company drilled additional wells using grant money from the USDA. A USDA inspector noted that the well drilling had caused a significant amount of sedimentation in a downstream pond. The type of sediment found in the pond matched the material present at the drilling site. In addition, the drilling site remained unvegetated and with poor soil conditions. Sediment from the drilling site drains into a small onsite pond and into Sawpit Canyon, which drains to Silverwood Lake (Phillips pers. comm. 2000a).

Urban development is around Lake Gregory in the southern part of the watershed, and urban runoff during wet periods could reach Lake Gregory. Lake Gregory drains to Silverwood Lake via Houston Creek.

7.3.3.4 Animal Populations

Grazing has not occurred in the watershed since 1990 (DWR 1996). A total of 1,950 acres on the east side of the lake provided grazing until the permit was rescinded.

There is also a substantial but unquantified wild animal population in the watershed. Wild animals as with grazing animals are a potential source of pathogens. The types of animals present in the watershed were described in Section 7.3.1, Watershed Description.

7.3.3.5 Algal Blooms

Nuisance algal blooms have occurred on occasion in Silverwood Lake and have been controlled through the application of copper sulfate. Algal growth is also a problem in Lake Gregory, which drains into

Silverwood Lake via Houston Creek. Algae are controlled in the creek with application of Cutrine, a proprietary chelated copper compound. Applications are typically made from May through September during most years.

7.3.3.6 Agricultural Activities

There is no known agriculture activity in the watershed. The Silverwood Lake SRA uses mechanical means rather than pesticides to control nuisance weeds around the lake. However, herbicide chemicals may be contained in the natural inflows to the lake because of uses in the forested lands of the watershed (Brown and Caldwell 1990).

7.3.3.7 Unauthorized Activity

Leaking Underground Storage Tanks

Sanitary Survey Update 1996 reported that two 2,000-gallon leaking underground storage tanks at a DWR facility at Cedar Springs Dam were removed in 1994. The leaking tanks were below the elevation of the dam and were not considered to have affected SWP water (DWR 1996).

7.3.3.8 Geologic Hazards

Silverwood Lake lies approximately 10 miles north of the San Andreas Fault zone. This presents the possibility of damage to SWP facilities in the event of seismic activity. If the outlet tower were damaged, deliveries on the East Branch would halt. This would create a water supply problem for much of Southern California. The inlet tower for the San Bernardino Tunnel was replaced in 1996 to meet seismic requirements and greatly reduce this threat (DWR 1994).

7.3.3.9 Land Use Changes

The Silverwood Lake watershed remains a mountainous, relatively undeveloped region. However, urban development has encroached on Lake Gregory in the southern part of the watershed. There were 2 major construction projects in the watershed between 1996 and 1999. A new intake tower for the San Bernardino Tunnel had to be constructed to meet upgraded seismic requirements. Additionally, the CLAWA installed a new clearwell and 2 back flush tanks to expand its capacity and meet increased regulatory demands.

San Bernardino Tunnel Intake Reconstruction Project

The San Bernardino Tunnel Intake is a crucial element of the East Branch, and failure of the structure would result in an interruption in deliveries to contractors serving much of Southern California. Studies by DWR determined that the tunnel intake did not meet seismic standards. The proximity of major geologic faults established the possibility of

seismic activity in the area. Replacement of the existing intake tower, which was the preferred design alternative, offered several advantages over strengthening the existing tower. Replacement would provide a superior design, reduce the amount of lake drawdown required during construction, and minimize interruption of downstream deliveries.

Most of the environmental effects associated with the project stemmed from drawing down the lake to facilitate the construction. The lake surface was lowered in 2 phases. In the 1st phase surface elevation was lowered from 3,353 feet to 3,310 feet. The lake surface remained at this elevation for about 11 months, from November 1994 through the end of 1995. In January 1995, the lake was lowered to surface elevation of 3,260 feet, 93 feet below the original lake elevation. The 2nd phase drawdown lasted about 3 months. Reservoir refilling began in March 1996 and lasted through September 1996 (DWR 1994).

The project had significant environmental impacts on air quality, biological resources, aesthetics, recreation, and water quality. The air quality concerns were related to increased particulate matter levels because of construction dust. The biological resources that would be affected by the lake draw down include the fisheries and avian species. The project could have had a significant effect on the endangered bald eagles, which have been observed around the lake. Mitigation measures developed to protect the fisheries concentrated on habitat enhancement (DWR 1997). To combat the loss of habitat caused by lake drawdown, artificial habitat structures and aquatic vegetation were placed along the shore of the lake.

Project construction had negative impacts on recreation. During the 1st phase drawdown, the most affected activities were swimming and nonmotorized boating. During the 2nd phase draw down, boats could not be launched and the marina boat slips were beached. Almost all boating and water-related recreation was suspended (DWR 1995). The loss of recreation activities, along with the aesthetic impacts of the construction, led to decreased numbers of park visitors in 1995 and 1996.

Water quality concerns over the intake tower construction were related to turbidity. The bare soil left by the lake drawdown is prone to erosion and may have caused an increase in lake turbidity levels during storm events. This is discussed in Section 7.3.4, Water Quality Summary.

Crestline-Lake Arrowhead Water Agency Tank Construction Project

In 1999, the CLAWA constructed 3 new tanks at its drinking water treatment plant adjacent to the lake.

The tanks were added to improve the treatment process to comply with increasingly stringent surface water treatment rules (Webb 1998). The current plant capacity is 3 mgd. To treat allocated volumes during peak conditions, CLAWA will need to expand plant capacity to 10 mgd. The project involved the construction of a 2.3-million gallon clearwell and two 0.25-million gallon backwash supply tanks. All tanks required grading and installation of cement pads. An estimated 8,000 cubic yards of material were excavated to grade the platforms. Access roads and additional fencing were added.

Water quality concerns associated with the project were related to soil erosion and increased turbidity. Grading and heavy construction activity was estimated to impact about 0.6 acres of land (Webb 1998). Upon completion of the project, surface runoff will be diverted around the new pads into existing discharge points. The new roads and pads were constructed with drainage swales and berms to reduce erosion potential, and the excavated areas were revegetated.

7.3.4 WATER QUALITY SUMMARY

7.3.4.1 Watershed

Water quality data for the 1996 through 1999 period are presented in Table 7-17. With the exception of 1 manganese sample that exceeded its

secondary MCL in February 1997, all parameters were below drinking water MCLs and applicable Article 19 objectives. Water quality at Silverwood Lake is influenced by SWP inflows, natural inflows, and contamination sources such as recreation within the watershed. On a yearly average, natural inflows are minor compared to SWP inflows. However, natural inflows can exert significant influence over reservoir water quality during storm events. Water quality at Silverwood Lake presents several concerns to SWP contractors. The most prevalent are high turbidities, algal blooms, and DBPs.

Minor elements that were detected in 2 or more samples include arsenic, boron, copper, iron, aluminum, manganese, and zinc (Table 7-17). Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations as the value of the detection limit; however, statistics were not calculated for parameters with 2 or fewer detections. Elements detected in a high percentage of samples, although at low concentrations include arsenic, boron, and copper. The only minor element that exceeded its respective MCL was manganese. One manganese sample (0.403 mg/L) exceeded the secondary MCL of 0.05 mg/L. All other results were an order of magnitude below the MCL.

Table 7-17 Silverwood Lake at Tunnel Inlet, Feb 1996 to Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	19	18	15	26	17-20	1	16/16
Chloride	42	45	10	62	27-57	1	16/16
Total Dissolved Solids	198	202	148	246	156-231	1	16/16
Hardness (as CaCO ₃)	85	88	62	94	74-92	1	16/16
Conductivity (µS/cm)	343	353	242	426	270-406	1	16/16
Magnesium	9	10	6	11	6-11	1	16/16
Sulfate	30	28	11	48	24-42	1	16/16
Turbidity (NTU)	4	4	1	10	2-7	1	13/13
Minor Elements							
Arsenic	0.002	0.002	<0.001	0.003	0.002-0.003	0.002	15/16
Boron	0.1	0.1	<0.1	0.2	0.1-0.2	0.1	15/16
Copper	0.004	0.004	0.002	0.006	0.002-0.005	0.002	12/16
Iron	0.009	0.005	<0.005	0.045	0.005-0.016	0.005	3/16
Aluminium	N/A	N/A	<0.01	0.03	N/A	0.01	2/16
Manganese	0.031	0.005	<0.005	0.403	0.005-0.015	0.005	4/16
Zinc	N/A	N/A	<0.005	0.050	N/A	0.005	2/16
Nutrients							
Total Kjeldahl Nitrogen (as N)	0.5	0.4	0.2	0.9	0.3-0.8	0.1	28/28
Nitrate (as NO ₃)	1.9	2.0	0.5	3.5	1.0-2.5	0.1	16/16
Nitrate+Nitrite (as N)	0.48	0.48	<0.01	0.77	0.26-0.65	0.01	47/48
Total Phosphorus	0.09	0.09	0.02	0.15	0.06-0.11	0.01	48/48
OrthoPhosphate	0.07	0.08	<0.01	0.11	0.04-0.10	0.01	41/48
Misc.							
Bromide	0.11	0.11	0.09	0.14	0.09-0.13	0.01	3/3
pH (pH unit)	7.7	7.5	6.9	8.9	7.0-8.6	0.1	8/8

Source: DWR O&M Division database, May 2000

Notes: Bromide and pH data from Feb 1999 to Aug 1999 and Feb 1998 to Nov 1999, respectively

Total Kjeldahl Nitrogen data from Jan 1996-March 1998 only

Statistics include values less than detection limit, if applicable

Total Dissolved Solids

TDS concentrations in Silverwood Lake ranged from 148 to 246 mg/L and averaged 198 mg/L (Table 7-18). All TDS results were well below the recommended secondary MCL of 500 mg/L. TDS concentrations in Silverwood Lake during 1996 to 1999 were similar and slightly lower than SWP inflows at Check 41. TDS levels measured at the Devil Canyon afterbay downstream of Silverwood Lake on the East Branch of the California Aqueduct were also very similar to levels measured in Silverwood Lake.

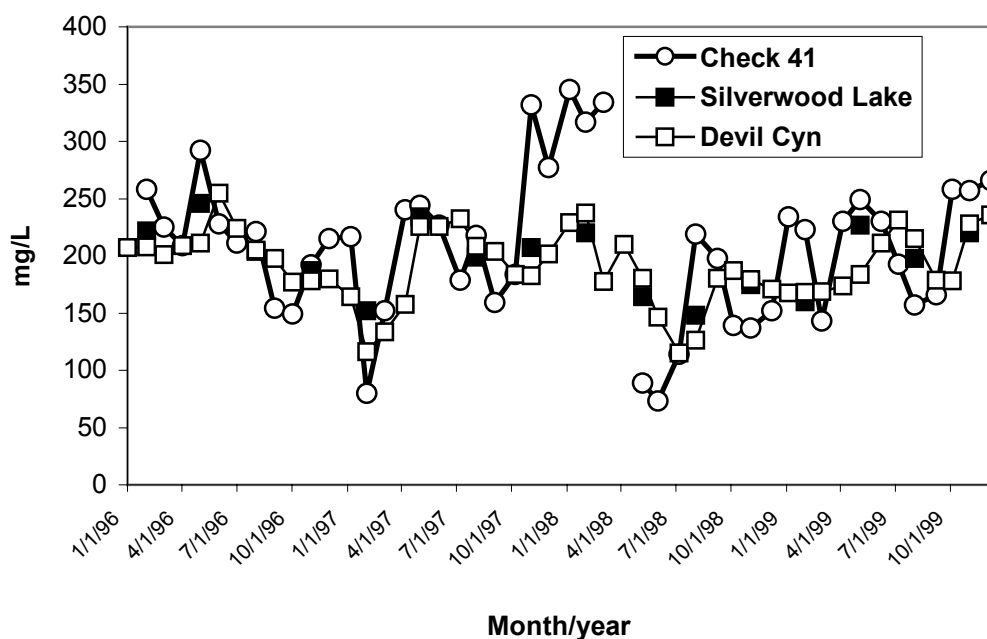
Figure 7-17 illustrates TDS concentrations at Check 41, Silverwood Lake, and Devil Canyon. With the exception of greater variability at Check 41, TDS concentrations remain very similar from Check 41 to Silverwood and then to Devil Canyon. The peak TDS concentrations in Silverwood Lake were observed in May of most years. High concentrations were also observed in February 1998, during the El Niño storms. High TDS concentrations in Silverwood Lake appear to correlate with high TDS concentrations at Check 41. This observation indicates that TDS concentrations in Silverwood Lake are much more influenced by SWP inflows than

natural inflows. It appears that natural inflows and activities in the Silverwood Lake watershed do not have a significant effect on TDS levels.

Table 7-18 Silverwood Lake and Check 41 TDS and Chloride (mg/L)

	Mean	Median	Min	Max
Check 41				
TDS	208	217	73	345
Chloride	48	48	2	107
Silverwood				
TDS	198	202	148	246
Chloride	41.6	45	10	62
Devil Canyon				
TDS	191	185	115	255
Chloride	41	41	5	65

Figure 7-17 TDS at Check 41, Silverwood Lake, and Devil Canyon



Source: DWR O&M Division database, May 2000

Chloride is an important component of TDS that is a good indicator of water quality sources and mixing. Chloride concentrations followed a similar pattern as TDS. Chloride concentrations decreased slightly from Check 41 to Silverwood Lake (Table 7-18). Chloride concentrations in Silverwood Lake and Devil Canyon were very similar. Chloride concentrations in Silverwood Lake ranged from 10 to 62 mg/L and averaged 41.6 mg/L. All chloride concentrations were well below the secondary drinking water MCL of 250 mg/L.

Nutrients

High concentrations of nutrients in source waters contribute to nuisance algal growth and eutrophication of the Silverwood Lake. Phosphorus and nitrogen are the primary nutrients that influence algal growth. Nutrient concentrations in Silverwood Lake are a reflection of SWP inflows at Check 41 with observed values being very similar to those at Check 41 (Table 7-17). This is most likely because of the short residence time in the lake (20 to 30 days), high SWP inflows, and generally low level of natural inflow.

In the 1970s, algal growth in Silverwood Lake was controlled through the application of copper sulfate (last application was in 1976). Algal growth is also a problem in Lake Gregory, which drains into Houston Creek and on to Silverwood Lake. The algal growth is controlled through the application of Cutrine, a proprietary chelated copper compound that is applied May through September of most years (Ryder pers. comm. 1999).

Mean and maximum values at Silverwood Lake were within the range of and commonly below respective values at Check 41 for Kjeldahl nitrogen, nitrate/nitrite, total phosphorous, and orthophosphate. Total phosphorus levels in Silverwood Lake ranged from 0.02 to 0.15 mg/L and averaged 0.09 mg/L. Orthophosphate ranged from 0.01 to 0.11 mg/L and averaged 0.07 mg/L. Kjeldahl nitrogen (as N) ranged from 0.2 to 0.9 mg/L and averaged 0.5 mg/L, almost exactly the same as Check 41. Nitrate and nitrite levels (as N) ranged from 0.04 to 0.77 mg/L and averaged 0.48 mg/L, slightly lower but similar to Check 41. Based on this data, it appears that activities in the Silverwood Lake watershed do not

contribute a significant additional nutrient load to the reservoir.

Nutrient concentrations also tend to follow a seasonal trend in reservoirs, as described for Castaic Lake, with concentrations decreasing during the summer growing season because of algal utilization. Figure 7-18 illustrates the seasonal trend of nutrient concentrations in Silverwood Lake. Periods of unexpected higher concentrations during the growing season (1996 and 1997) could be caused by higher levels of SWP inflows at these times.

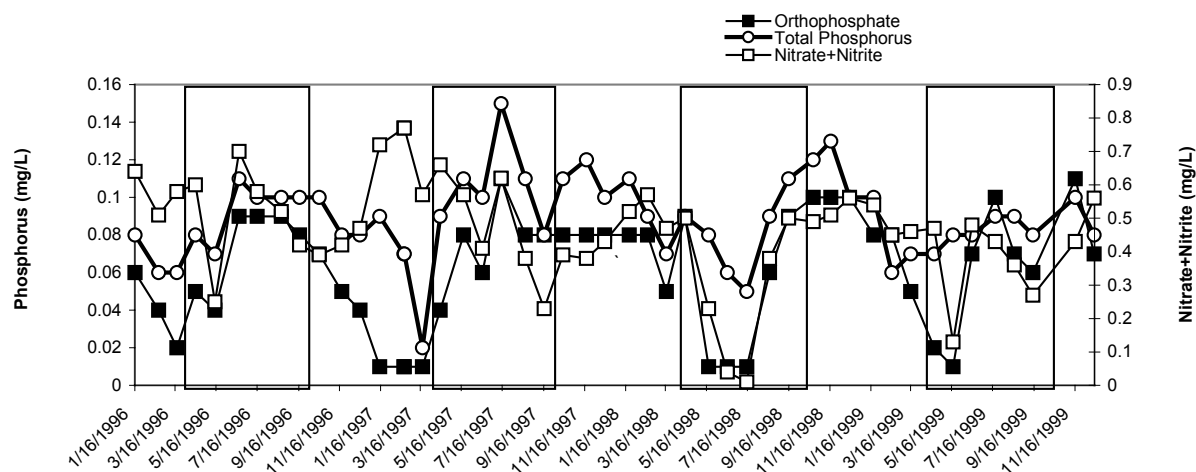
Turbidity

Turbidities ranged from 1 to 10 NTUs, with a mean of 4.2 NTUs (Table 7-17). Turbidity in Silverwood Lake was both lower and much less variable than Check 41 during the 1996 to 1999 period. Turbidities at Check 41 ranged from 2 to 140 and averaged 25 NTUs.

Turbidity is monitored monthly along with other conventional parameters. Inflows from the watershed and SWP significantly affected Silverwood Lake turbidity. Quarterly monitoring failed to reveal a spike in lake turbidity that occurred in late February 1996. Heavy rainfall combined with construction activities related to the reconstruction of the outlet tower led to turbidity readings as high as 154 NTUs at the Devil Canyon afterbay. This turbidity peak lasted approximately 7 days and disrupted treatment plant operations at the Mills FP (MWDSC 1996).

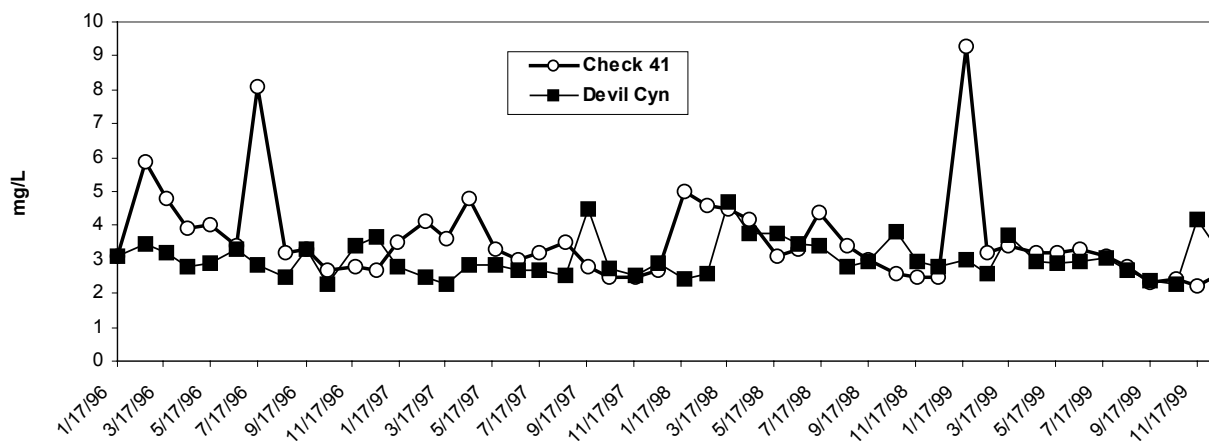
Total Organic Carbon and Alkalinity (DBP precursors)

TOC data were not collected at Silverwood Lake during the 1996 to 1999 period. However, TOC data were available for Check 41 and Devil Canyon afterbay. TOC at Check 41 ranged from 2.2 to 9.3 mg/L and averaged 3.6 mg/L. At Devil Canyon, TOC ranged from 2.3 to 4.7 mg/L and averaged 3.03 mg/L. With the exception of the high-range variability, TOC levels at Devil Canyon and Check 41 were very similar (Figure 7-19). TOC spikes in March and September 1996 and February 1999 did not appear to affect Silverwood Lake TOC levels. Alkalinities at Silverwood Lake and Devil Canyon were nearly identical and ranged from 52 to 97 mg/L and averaged 72 and 69 mg/L, respectively. Levels were below 60 mg/L on only 4 occasions from 1996 to 1999.

Figure 7-18 Seasonal Variation in Nutrient Concentrations in Silverwood Lake, 1996 to 1999

Source: DWR O&M Division database, May 2000

Boxed areas represent approximate algal growth season, May through October.

Figure 7-19 TOC Concentrations at Silverwood Lake Outlet and Check 41

Source: DWR O&M Division database, May 2000

As shown in Figure 7-19, TOC concentrations at both Check 41 and Devil Canyon exceeded the proposed drinking water protection standard of 3 mg/L frequently, although there was no apparent connection between the two. TOC did not appear to increase as a result of watershed activities at Silverwood Lake.

Quarterly bromide sampling at Silverwood Lake began in 1998. Only 3 samples were collected during this time. Bromide ranged from 0.09 to 0.14 mg/L.

A more extensive data set exists for Check 41. Bromide at Check 41 ranged from 0.01 to 0.38 mg/L between 1996 and 1999. The mean bromide concentration for this period was 0.15 mg/L. These values exceeded the proposed drinking water standard of 0.05 mg/L for bromide. As with TOC, bromide levels did not appear to change significantly or increase as a result of watershed activities in Silverwood Lake. Therefore, there do not appear to be any significant sources of TOC and bromide in the

watershed, and their concentrations in Silverwood Lake are a reflection of water quality conditions at Check 41 and Delta source waters.

MTBE

MWDSC and the DWR collected samples at the Sawpit Canyon boat ramp and the Silverwood Lake outlet (inlet to the San Bernardino Tunnel) (Figure 7-16). Only surface samples were collected from the Sawpit Canyon boat ramp. Mid-depth and deep water samples were collected at the lake outlet. In 1997, Silverwood Lake was thermally stratified from May through July. The depth to the thermocline

ranged from 20 to 26 meters. Results are presented in Table 7-19.

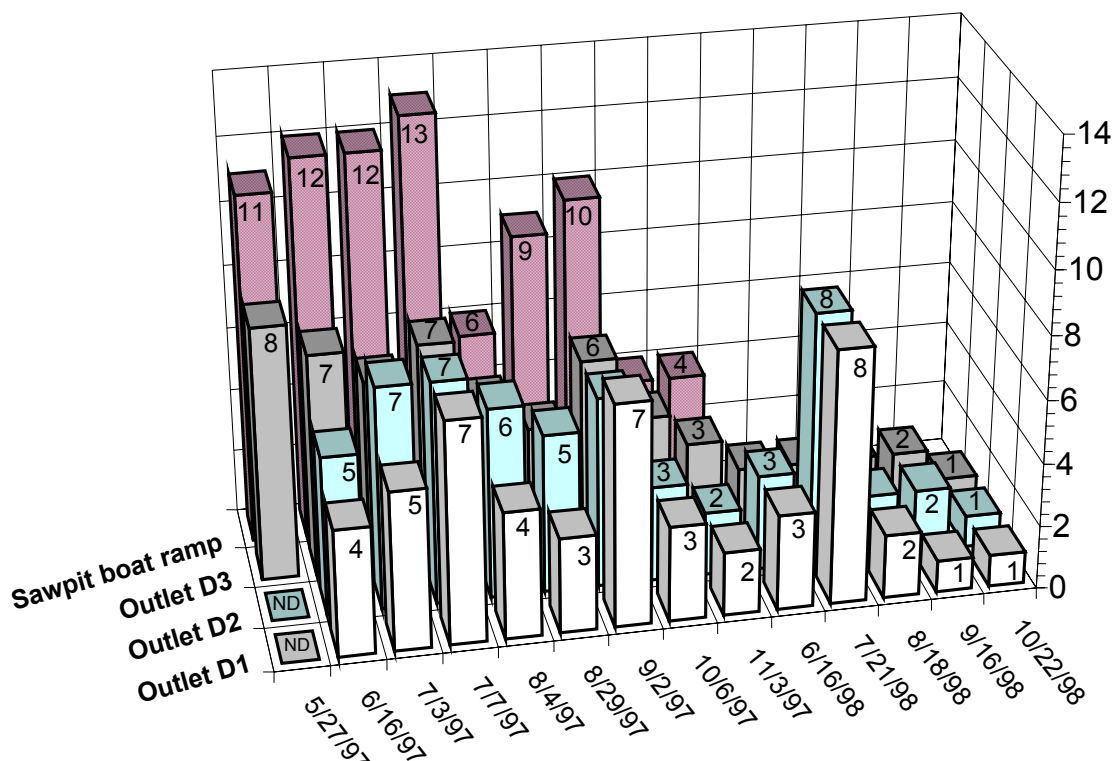
MTBE concentrations in Silverwood Lake rose throughout the summer of 1997 to peak levels in July and August. Concentrations at the boat ramp reached levels near the primary MCL of 13 µg/L (Figure 7-20). Concentrations at the outlet were above the secondary MCL of 5 µg/L for most of the summer season but never exceeded the primary MCL. MTBE concentrations at all locations fell to levels below the secondary MCL in the fall after lake stratification decreased and recreational use declined.

Table 7-19 Summary of MTBE Concentrations in Silverwood Lake (µg/L)

MWDSC Sampling	Outlet (1997)		Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion)				
Range	2.6 to 6.9	ND to 1.1	2.4 to 6.5	ND to 1.1
Mean	4.1	ND	4.0	ND
Bottom (Hypolimnion)				
Range	2.6 to 4.1	N/S	N/S	N/S
Mean	3.3	N/S	N/S	N/S
DWR Sampling	Outlet (1997/1998)		Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion D1+D2)				
Range	ND to 8.0	N/S	4.0 to 13	N/S
Mean	4.4	N/S	9	N/S
Bottom (Hypolimnion)				
Range	ND to 7	N/S	N/S	N/S
Mean	3.5	N/S	N/S	N/S

Note: Surface samples include samples collected from 0.5 to 15 meters

ND = Not Detected. N/S = Not Sampled

Figure 7-20 Summary of MTBE Concentrations in Silverwood Lake

Data source: DWR 1999, DWR Operations and Maintenance unpublished data 1998

Notes: Outlet D1 = 0.5 m, Outlet D2 = 6-15 m, Outlet D3 = >15 m

MTBE concentrations observed at the Sawpit boat ramp were higher than at the outlet (Figure 7-20). MTBE concentrations in surface samples from the boat ramp ranged from 4 to 13 µg/L with a mean of 9 µg/L. Surface samples from the inlet to the outlet ranged from ND to 8 µg/L with a mean of 4.4 µg/L.

MTBE concentrations in the epilimnion were nearly homogenous. Surface values were within a few units of the mid-depth and deep water samples. In 1997, surface samples at the outlet ranged from 1.1 to 7.4 µg/L with a mean of 5.1 µg/L. The mean of the mid-depth samples was 5.2 µg/L. The deep water samples were collected at depths ranging from 15 to 20 meters. In 1997, all of the deep water samples collected were sampled from above the thermocline except for 1 sample collected 27 May 1997. The mean of the deep water samples was 3.1 µg/L.

Samples were collected at both the outlet and the boat ramp before and after the 4th of July and Labor Day weekends. These weekends represent the periods of highest recreational use at Silverwood

Lake. MTBE concentrations rose only 1 µg/L at both sampling stations after the 4th of July weekend. MTBE concentrations increased by 1 µg/L at the boat ramp over the Labor Day weekend and 2 µg/L at the outlet.

Another group of compounds commonly associated with fuel contamination—benzene, toluene, ethyl benzene, and xylene (BTEX) and MTBE—were detected with MTBE in 8 of 9 surface samples collected by DWR at the boat ramp in 1997. BTEX compounds were not detected in any of the samples collected by DWR at the outlet.

Taste and Odor

MIB and geosmin levels were homogenous across the surface of the lake. MIB concentrations at the lake inlet ranged from ND to 8 ng/L and averaged 3.2 ng/L (Table 7-20). MIB was detected in 33% of the surface samples collected at the inlet. Similarly, MIB was detected in 23% of the surface samples collected at the lake outlet. MIB ranged from not detected (ND) to 8 ng/L and averaged 3.3 ng/L. Geosmin

concentrations ranged from ND to 5 ng/L at both the inlet and the outlet. The mean geosmin concentration in surface samples collected at the lake inlet was 2.6 ng/L; at the lake outlet, it was 2.4 ng/L (Figure 7-21). Most of the geosmin and MIB found in the lake are believed to have been produced in the East Branch of the California Aqueduct not in the lake (Faulconer pers. comm. 2001).

MIB and geosmin concentrations at Silverwood Lake were detected at uniform concentrations

throughout the depth of the water column but were generally below the taste and odor detection limit of 5 to 10 ng/L (Figure 7-21 lower chart).

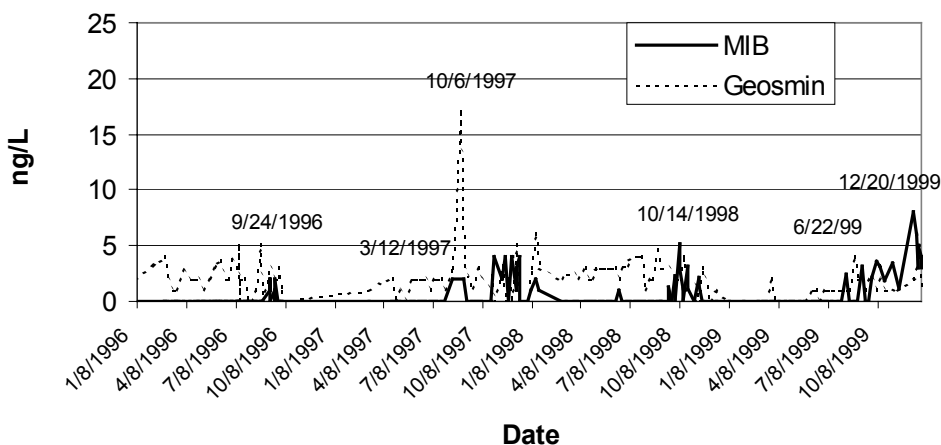
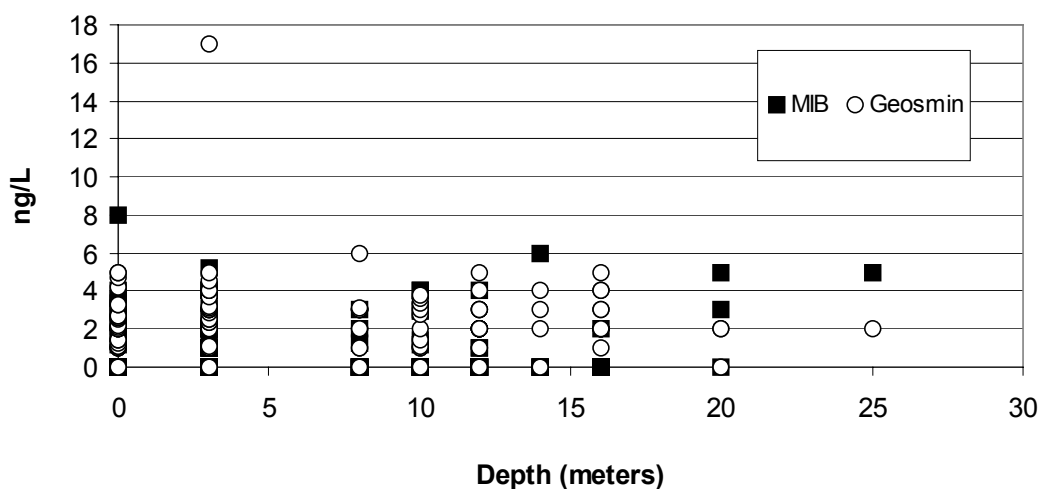
Concentrations remained at a fairly low and constant value throughout the year.

Reservoir management practices such as selective depth withdrawal are used to minimize the amount of MIB and geosmin in lake outflow sent to the Henry J. Mills FP via the Devil Canyon afterbays.

Table 7-20 MIB and Geosmin Concentrations at Silverwood Lake, 1996 to 1999 (ng/L)

	MIB	Geosmin
Silverwood Inlet-Surface (0 m)		
Range	ND to 8.0	ND to 5.0
Mean	3.2	2.6
Percent of samples with detects	33%	51%
Silverwood Inlet-All Depths		
	MIB	Geosmin
Range	ND to 8	ND to 22
Mean	3.0	2.4
Percent of samples with detects	25%	56%
Silverwood Outlet-Surface (0 m)		
	MIB	Geosmin
Range	ND to 8.0	ND to 5.0
Mean	3.3	2.4
Percent of samples with detects	23%	64%
Silverwood Outlet- All Depths		
	MIB	Geosmin
Range	ND to 8.0	ND to 17
Mean	2.7	2.4
Percent of samples with detects	24%	70%
Mills FP Influent		
	MIB	Geosmin
Range	ND to 6.0	ND to 13
Mean	2.5	2.2
Percent of samples with detects	10%	55%

Note: Mean values do not include samples where the analyte was not detected
ND = Not Detected

Figure 7-21 MIB and Geosmin Levels at the Silverwood Lake Outlet, 1996 to 1999**MIB and Geosmin Levels by Depth - Silverwood Lake Outlet Tower**

7.3.4.2 Water Supply System

MWDSC Henry J. Mills Filtration Plant

MWDSC routinely monitors source (influent) and treated (finished) water quality to meet primary and secondary MCLs contained in Title 22 of the California Code of Regulations. The parameter categories in Title 22 for these MCLs were presented in the Castaic Lake water quality section.

MWDSC's major concerns associated with treating SWP water are occasional high turbidities, DBP precursors, and taste and odor compounds produced by algal blooms. Both source and finished waters at the Mills FP were below applicable primary and secondary MCLs during the 1996 through 1999

(Torobin pers. comm. 2000). Data were obtained from the MWDSC laboratory database for 1996 to 1999 and sampling at the Devil Canyon afterbay (for example, source water), summaries from annual reports, and consumer confidence reports for this period.

Trace metals and organic compounds are discussed first because they are either detected at low levels or not routinely detected at all and are, therefore, not of concern. The main parameters of concern selected for further discussion are presented after trace metals and organics.

Aluminum, arsenic, barium, iron, manganese, and strontium were the only trace metals detected in Mills FP influent, but at very low levels. Aluminum

averaged 0.3 mg/L over the 1996 to 1999 period, slightly above the secondary MCL (0.2 mg/L). All other trace metals were detected at levels below applicable MCLs except for iron, which exceeded its secondary MCL on 1 occasion (0.4 mg/L). Arsenic levels in Mills FP influent ranged from 0.007 to 0.029 mg/L and averaged 0.02 mg/L, below the MCL of 0.05 mg/L. However, some of these values are greater than the proposed MCL of 0.01 mg/L being evaluated for arsenic. The same trace metals were detected in Mills FP finished water, but at even lower levels.

With the exception of MTBE, no VOCs, SVOCs, or other organic compounds were detected in either Mills FP source or finished waters (Koch pers. comm. 2000; Torobin pers. comm. 2000a).

MTBE levels in Mills FP influent were much lower than ambient lake levels and ranged from nondetect to 5.9 mg/L. The average for the 1996 to 1999 period was 1.6 mg/L. These levels were well below the MCL of 13 µg/L. MTBE was never detected in Mills FP finished water.

TOTAL DISSOLVED SOLIDS. TDS levels in Mills FP source water are a direct reflection of levels found in Silverwood Lake. TDS in Mills FP influent ranged from 115 to 255 mg/L; the 1996 to 1999 average was 191 mg/L. TDS levels at the Silverwood outlet averaged 198 mg/L. TDS levels in Mills FP finished water were similar to levels observed in plant influent. Annual averages ranged from 180 to 243 mg/L. The annual average influent and finished water TDS levels were very closely matched for each individual year.

Chloride concentrations in Mills FP influent were very similar to chloride concentrations in SWP inflows at Check 41. Chloride concentrations in Mills FP influent ranged from 5 to 65 mg/L and averaged 41 mg/L. The average chloride concentration at the Silverwood Lake outlet was 41.6 mg/L, while the average value at Check 41 was 48 mg/L. Chloride levels in Mills FP finished water were slightly higher than levels in plant influent. Average annual levels in Mills FP finished water ranged from 44 to 61 mg/L.

TURBIDITY. MWDSC experienced significant treatment difficulties at the Mills FP because of high turbidity in source water at Devil Canyon from 1996 to 1999. The difficulties include increased chemical usage, increased solid waste, lower filter run lengths, increased finished water turbidity, and plant flow restrictions.

Sources of turbidity include storm water runoff and high turbidity in SWP inflows from the California Aqueduct at Check 41 and construction

activities at Silverwood Lake. Turbidity poses the greatest difficulty during the winter months. A spike in influent turbidity in February 1996 caused the Mills FP to be temporarily shut down. Turbidities as high as 154 NTU were reported (MWDSC 1996). The spike was caused by heavy rainfall in the Silverwood Lake watershed during the time that the lake was drawn down to facilitate the construction of the new outlet tower. However, MWDSC was still able to meet all operation and plant performance criteria required by the California Department of Health Services (DHS) during the 7-day high turbidity event (MWDSC 1996).

Turbidity values in Mills FP influent ranged from 0.5 to 41 NTUs and averaged 6.7 NTUs. These values were above the range of turbidities reported in Silverwood Lake (1 to 10 NTUs). Annual average turbidity in Mills FP finished water ranged from 0.06 to 0.08 NTUs and were well below the secondary turbidity MCL of 5 NTUs.

NUTRIENTS. Nutrients contribute to algal growth and the production of the malodorant compounds MIB and geosmin. Nitrate (as NO₃) is the only nutrient parameter that is regularly monitored in Mills FP influent and finished water. Nitrate values at the Mills FP were well below the primary MCL of 45 mg/L in both plant influent and plant finished water. However, nitrate levels of concern for algal growth are much lower than the MCL.

Nitrate levels in Mills FP influent and finished water were very similar to levels observed in Silverwood Lake. Nitrate levels in Mills FP influent ranged from 0.5 to 3.7 mg/L and averaged 2.1 mg/L. Annual finished water average concentrations ranged from 1.8 to 2.5 mg/L. Nitrate concentrations in Silverwood Lake averaged 1.9 mg/L. Annual averages for both nitrate and nitrate+nitrite (as N) in finished waters were usually the same and ranged from 0.18 to 0.69 mg/L, well below the MCL of 10 mg/L.

TOTAL ORGANIC CARBON AND ALKALINITY (DBP PRECURSORS). TOC and bromide in source water react with disinfectants at the Mills FP to produce DBPs such as TTHMs and HAAs and bromate. TOC and bromide are monitored in Mills FP influent and finished water. TTHMs are monitored in Mills FP finished water only. The current TTHM MCL is 100 µg/L. Although MWDSC did not exceed this MCL at the Mills FP, TOC and bromide levels are too high to comply with the Stage 1 D/DBP Rule-proposed TTHM MCL of 80 µg/L. Additionally, member agencies that receive treated water from Mills FP experience higher TTHM levels because of continued

formation of TTHMs in MWDSC's distribution system (MWDSC 2000).

Water quality data for TOC and alkalinity in Mills FP influent and finished waters and Check 41 are presented below in Table 7-21.

Table 7-21 Comparison of TOC and Alkalinity at Mills FP (mg/L)

Parameter/ Value	Check 41	Mills FP	
		Influent	Finished
TOC			
Range	2.2-9.3	2.3-4.7	2.0-2.5 ^a
Average	3.6	3.1	2.3 ^b
Alkalinity			
Range	41-109	52-91	59-74 ^a
Average	70	69	68 ^b

^a Range of 1996-99 annual averages only

^b Average of 1996-99 annual average data

Check 41 TOC levels frequently exceeded the CALFED-target drinking water protection standard of 3 mg/L at the export pumps at Banks, while Mills FP influent exceeded it less frequently but with a high proportion of values in the 2.5 to 2.9 mg/L range. Check 41 TOC levels were similar to Mills FP influent but had a much higher high-range value, while Mills FP influent and finished water were similar. Alkalinities were similar at all locations, and average values were within the 60 to 120 mg/L proposed in the D/DBP Rule for 25% TOC removal at TOC values from >2-4 mg/L. TOC values in Mills FP influent were below 4 mg/L except for 3 samples over the 1996 to 1999 period.

Bromide levels in Silverwood Lake and Mills FP influent were very similar. Mills FP influent values ranged from 0.03 to 0.22 mg/L and averaged 0.13 mg/L. These values also exceeded the CALFED-target drinking water protection standard of 0.05 mg/L for bromide.

TTHM levels in Mills FP finished water ranged from 41 to 67 µg/L and averaged 57 µg/L on an annual average basis (1996 data not available). Finished water quality always met the current MCL of 100 µg/L, but MWDSC will be challenged with the proposed MCL of 80 µg/L in the Stage 1 D/DBP Rule.

The practice of using chlorine for primary disinfection results in TTHMs typically greater than the proposed MCL of 80 µg/L in the Mills FP service areas. In addition, the Stage 1 D/DBP Rule will require enhanced coagulation removal of TOC, unless certain exceptions are met (25% removal from >2-4 mg/L and alkalinity of 60 to 120 mg/L). MWDSC has decided to convert the Mills FP from chlorination to ozonation for primary disinfection as

the most effective solution to comply with Stage 1 and future Stage 2 requirements of the D/DBP Rule. The use of ozone and chloramines will reduce TTHMs to less than 40 µg/L, which will allow MWDSC to qualify for an exception to the enhanced TOC treatment component of the rule.

Although ozone disinfection will help reduce the levels of TTHMs in finished water, ozone also reacts with bromide in source waters to produce bromate, a powerful carcinogen and DBP regulated under the D/DBP Rule. Because of the relatively high bromide levels in SWP water, bromate levels that will typically be formed during ozonation would, without additional treatment measures, exceed the Stage 1 bromate MCL of 10 µg/L. MWDSC plans to control the amount of bromate formed in the ozonation process by lowering the pH to 7.0 or lower using sulfuric acid addition. Higher bromide concentrations may require pH reduction to 6.0. Further, if the future Stage 2 D/DBP Rule lowers the proposed bromate MCL to 5 µg/L, the frequency of pH adjustments would dramatically increase (MWDSC 2000).

TASTE AND ODOR. Mills FP influent had similar concentrations of MIB and geosmin to those observed at the Silverwood outlet tower. MIB was detected in about 10% of the samples collected at Mills FP between 1996 and 1999. The range was not detected to 6 ng/L, and the mean of all samples where MIB was detected was 2.5 ng/L. These data are similar to those for the Silverwood outlet tower (Table 7-20).

Geosmin was detected in about 55% of the samples collected at Mills FP. The average of detected values was 2.2 ng/L. This is very similar to values observed at the Silverwood outlet tower, which averaged 2.4 ng/L. Geosmin concentrations at Mills FP exceeded the taste and odor threshold of 5 to 10 ng/L on only 1 occasion in May of 1996.

Crestline-Lake Arrowhead Water Treatment Plant

The CLAWA treatment plant is adjacent to Silverwood Lake, near the inlet to the San Bernardino Tunnel (Figure 7-15). CLAWA treats 100% SWP water. CLAWA is subject to the same source water quality concerns as MWDSC: high turbidity, DBP precursors, taste and odor, and algae problems. CLAWA monitors for TTHMs and HAAs in treatment plant finished water. Quarterly averages ranged from 33 to 75 µg/L with the highest concentrations reported in the first 2 quarters.

CLAWA operated in compliance with all applicable primary and secondary MCLs for both influent and finished water. However, CLAWA is

often challenged to meet the TTHM MCL (Newell pers. comm. 2000). In order to meet Stage 1 D/DBP requirements, CLAWA will need to practice enhanced coagulation and pH adjustment. CLAWA is working with an independent engineering firm to optimize its treatment process.

In order to meet the 40 µg/L TTHM MCL proposed in the Stage 2 requirements, CLAWA will need to make significant improvements to its treatment process. CLAWA is considering adding ozone disinfection, membrane filtration, or UV treatment techniques (CLAWA 2000). All of these options represent significant expense to CLAWA.

San Gabriel Valley Municipal Water District

The SGVMWD does not treat and, therefore, does not monitor source or finished water. The SGVMWD takes SWP deliveries from a turnout at the Devil Canyon afterbay and conveys this water through its distribution system downstream to groundwater recharge facilities.

Pathogens

Pathogen issues related to Silverwood Lake are discussed in Chapter 12 for the Mills FP.

7.3.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

The significant contaminant sources and major water quality concerns at Silverwood Lake are related to both SWP source water and watershed activities. The main concerns associated with source water quality are DBP precursors (for example, TOC and bromide), taste and odor associated with algal growth in the reservoir, and occasional turbidity because of SWP inflow spikes and algal growth. The main water quality concerns associated with watershed activities include pathogens and MTBE from recreation, turbidity caused by construction activities and runoff, and pathogens and erosion from animal populations.

TOC and bromide do not appear to be significantly changed by watershed activities at Silverwood Lake. The major contributor of these parameters is the Delta via the California Aqueduct at Check 41. MCLs for these parameters are being met, but high levels of DBPs in Delta and aqueduct water present challenges meeting Stage 1 D/DBP Rule limits for TTHMs and bromate.

Algal blooms, caused in large part by high nutrient levels in source water, result in increased turbidity and production of MIB and geosmin—2 compounds causing taste and odor problems in water supplies. Nutrient levels were similar in inflows and outflows, and there was no evidence that watershed activities contributed to the existing nutrient load. Spikes from

the aqueduct and water delivery pipelines can also be a source of turbidity.

The most significant contaminant source and water quality concern associated with watershed activities is recreation. The water quality problems associated with recreational activities at Silverwood Lake are the contribution of pathogens, release of MTBE from motorized watercraft, and turbidity caused by erosion in camping and shoreline areas. Body-contact recreation is considered the most significant, although as yet unquantified, potential pathogen source. Also of concern for release of pathogens is the floating toilet (potential spills, leaks) and incidental waste releases from boats. In addition to the potential to cause disease in water recreationists, high concentrations of pathogens have the potential to overwhelm the Mills FP, especially under higher turbidities, and inhibit the required removal levels for pathogens under the IESWTR. MTBE, although high in the lake, was always below the MCL in Mills FP influent, but it still poses a potential threat to drinking water quality.

Besides algae and the SWP inflow, watershed activities such as construction and runoff were significant sources of turbidity at Silverwood Lake. Construction activities contributed to a high turbidity spike in February 1996. Storm water runoff combined with low lake levels to drive turbidity readings up to 154 NTUs. High turbidity in source water creates significant treatment difficulties for SWP contractors.

Populations of wild animals in the watershed are also a potentially significant pathogen loading source as would be cattle if grazing were to resume. However, the contributions from this source are not possible to assess with existing data.

The 4 WWTPs within the watershed, their collection systems, and sanitary facilities within the SRA have operated properly during the period of this study. Also, substantial improvements have been made to the treatment plant facilities; however, wastewater treatment and collection facilities continue to have the potential to contribute pathogens, DBPs, and nutrients to the reservoir in the event of a spill or system failure.

7.3.6 WATERSHED MANAGEMENT PRACTICES

Several agencies have management authority in the Silverwood Lake watershed. DWR constructed the reservoir and is primarily responsible for its operation. California States Parks is responsible for the management of the Silverwood SRA and has several policies in place to protect water quality, for example, limits on the number of recreationists. The DBW has regulatory authority over boating in the

SRA. Recreation presents the largest watershed management issue at Silverwood Lake, and activities often can be significant sources of contamination. Strategies to address and mitigate impacts on drinking water quality are being discussed in a water quality/recreation focus group in which DWR, state and county recreation departments and other agency staffs participate.

A large portion of the watershed is in the San Bernardino National Forest, which is administered by the USDA Forest Service. The Forest Service's role and powers are described in Section 7.1, Pyramid Lake. The Forest Service is working with private off-highway vehicle (OHV) users groups to develop strategies for minimizing their impact on the environment. The most important issue to water quality concerns would be erosion control practices.

The existing wastewater treatment plants and collection systems in the watershed present a potentially significant but currently low threat to water quality. The Regional Water Quality Control Board regulates wastewater treatment systems through NPDES permits, and unauthorized discharges such as spills or overflows are prohibited. Both the Crestline Sanitation District and the Pilot Rock WWTP are regulated by the NPDES permit system. The Crestline Sanitation District has made several facility improvements to guard against unauthorized wastewater releases, including the construction of 2 emergency storage reservoirs.

After recreation, the greatest threat to water quality from activity in the watershed is from construction and runoff. Changes in land use or activities such as

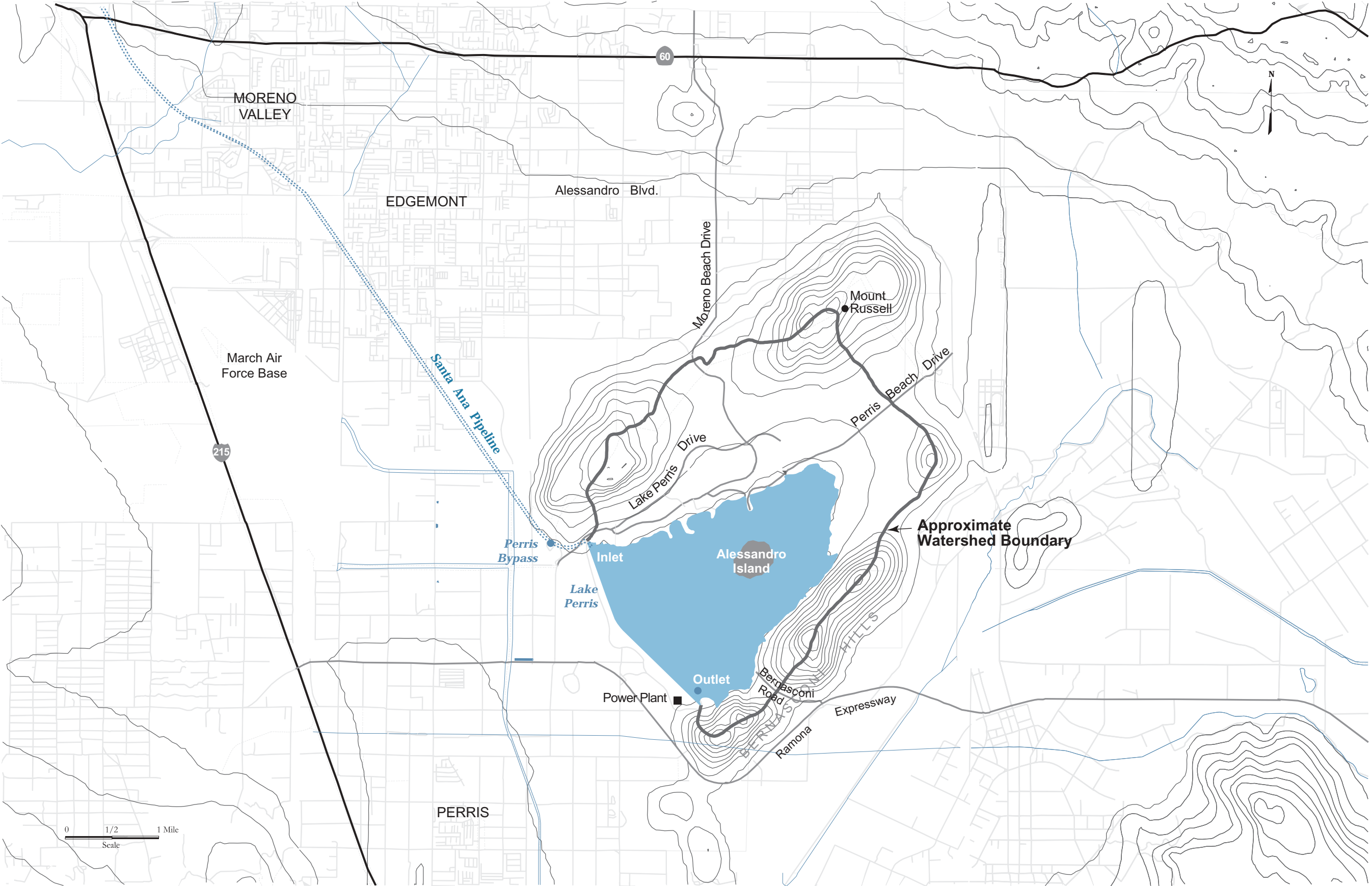
construction and development during wet periods can be a significant source of turbidity and other contaminants. Silverwood Lake is especially vulnerable to contamination from these activities because of its small watershed size and low hydraulic residence time, which can combine to quickly flush contaminants into the Devil Canyon afterbay and downstream water supply systems. No comprehensive watershed assessment/management program exists, and no BMPs are in place or proposed for implementation. Areas in need of BMPs include control of urban runoff in exposed areas and erosion control. Construction activities greater than 5 acres are required to obtain a general storm water NPDES permit for this purpose. However, it appears that stricter controls on these activities should be implemented.

7.4 LAKE PERRIS

7.4.1 WATERSHED DESCRIPTION

The terminal reservoir of the East Branch of the California Aqueduct is Lake Perris, which was completed in 1974. It lies in Riverside County, about 13 miles southeast of the city of Riverside and approximately 65 miles from downtown Los Angeles. Lake Perris is in the Moreno Valley, an area that has experienced rapid urban growth over the last several years. It is a multiuse facility, providing water storage, recreation, and fish and wildlife habitat (Figure 7-22).

Figure 7-22 Lake Perris Watershed Area



7.4.1.1 Land Use

The Lake Perris SRA, which is operated by California State Parks, occupies the majority of the watershed. The recreation area offers a variety of body-contact and nonbody-contact recreational opportunities. There is almost no other development in the watershed other than the recreational facilities associated with the lake. New residential and commercial development exists outside of the watershed in Moreno Valley. The Lake Perris Fairgrounds also lies immediately outside of the watershed, below the dam. March Field AFB lies approximately 3 miles to the west.

7.4.1.2 Geology and Soils

Rocks in the area consist of granite, quartz monzonite, granodiorite, and quartz diorite. The majority of the watershed is unconsolidated and semi-consolidated alluvium, lake, playa, and terrace deposits. The San Jacinto fault borders the eastern side of the watershed and is the only known major fault in the area.

Upland areas north, south, and east of the lake have well-drained sandy loams and fine sandy loams on granite rock (USDA 1971). The lake bed and shoreline areas consist of well drained sandy to sandy loam soils on alluvial fans. The Russell Mountains on the north and the Bernasconi Hills on the south form the watershed's topography. These rocky hills rise 1,200 feet from the floor of the Moreno and San Jacinto valleys.

7.4.1.3 Vegetation and Wildlife

Three types of vegetation exist within the watershed: coastal sage scrub, chaparral, and riparian. The sage scrub community is composed of various sages, desert encelia, brittlebrush, buckwheat, and cacti (Apante 1999). The chaparral community is made up of chamise, penstemon, and poison oak. The riparian zone lies along springs and around the lakeshore and is composed of willows, cattails, elderberry, and nettles.

There are numerous types of wildlife in the watershed, including quail, dove, ducks, geese, rabbits, and other small mammals include badgers, bobcats, coyotes, weasels, skunks, and snakes. Rodent populations include squirrels, mice, moles, and pocket gophers (Apante 1999). The watershed also contains prime habitat for the Stephen's Kangaroo rat, a federal endangered species. Migratory waterfowl winter at Lake Perris. Some species include pintails, widgeon, geese, whistling swans, egrets, herons, and pelicans. Hunting is allowed in the watershed. Game species include rabbits, ducks, geese, mourning doves, and valley quail. California Department of Fish and Game operates hunting areas for upland game in season at

designated areas. The recreation area also serves as a wildlife sanctuary to observe wildlife, with ducks and geese present during winter and shore birds most of the year.

7.4.1.4 Hydrology

The Lake Perris watershed encompasses approximately 16 square miles and is the smallest of the 4 Southern California reservoirs. There is no significant natural inflow to the reservoir, with only 3 small creeks in the north part of the lake. Neither runoff nor natural inflows are measured.

At 2,320 acres, Lake Perris has the largest surface area of the 4 Southern California SWP reservoirs (DWR 1999). However, it is a shallow reservoir. The mean depth is only 57 feet (Anderson 2000). This leads to an intermediate volume of 131,450 acre-feet at full pool. Lake Perris has a slightly larger surface area than Castaic Lake and yet has only half the capacity and a much smaller watershed.

Lake Perris becomes thermally stratified during summer months, confining introduced contaminants to the epilimnion (upper layer). The average volume of the epilimnion in Lake Perris was calculated to be 52,930 acre-feet (Anderson 2000), which represents about 40% of the total lake volume.

7.4.2 WATER SUPPLY SYSTEM

7.4.2.1 Description of Aqueduct/SWP Facilities

SWP water flows into Lake Perris from the Devil Canyon afterbay, through the Santa Ana Pipeline at mile 440.26, the terminus of the East Branch of the California Aqueduct. The covered pipeline presents minimal chance of contamination. In 1983, the Perris bypass and power plant were constructed. The bypass allows water to be delivered to MWDSC directly out of the aqueduct, before it goes into Lake Perris.

The MWDSC is the only agency contracting deliveries from Lake Perris. The agency wholesales this water to 27 member agencies that provide drinking water to about 17 million people. MWDSC reduced its use of Perris water during the period of this study (Table 7-22). Water quality concerns are cited as a primary reason MWDSC does not use its full entitlement of water from Lake Perris, but power generation revenue also plays a significant role in how the lake is operated (Faulconer pers. comm. 2001). The water that is delivered to MWDSC from Lake Perris is treated at the Robert A. Skinner treatment plant and the Mills FP. Water from Lake Perris is mixed with water from MWDSC's Colorado River Aqueduct. SWP water typically makes up less than 25% of the water treated at the Skinner plant

(Torobin pers. comm. 2000). Treated water from the Skinner plant is delivered to some communities in western Riverside County and San Diego County. Annual total deliveries from Lake Perris make up only 2% of MWDSC's maximum annual SWP entitlement.

contact recreation includes swimming, water skiing, and personal watercraft riding. Nonbody-contact recreation at Lake Perris includes camping, picnicking, horseback riding, sail and power boating, fishing, hiking, bicycling, hunting, and rock climbing (Figure 7-23).

7.4.3 POTENTIAL CONTAMINANT SOURCES

7.4.3.1 Recreation

Lake Perris SRA, which opened in 1974, fulfills the mandate that all SWP facilities provide recreational amenities and opportunities. Body-

Table 7-22 Water Deliveries from Lake Perris (acre-feet)

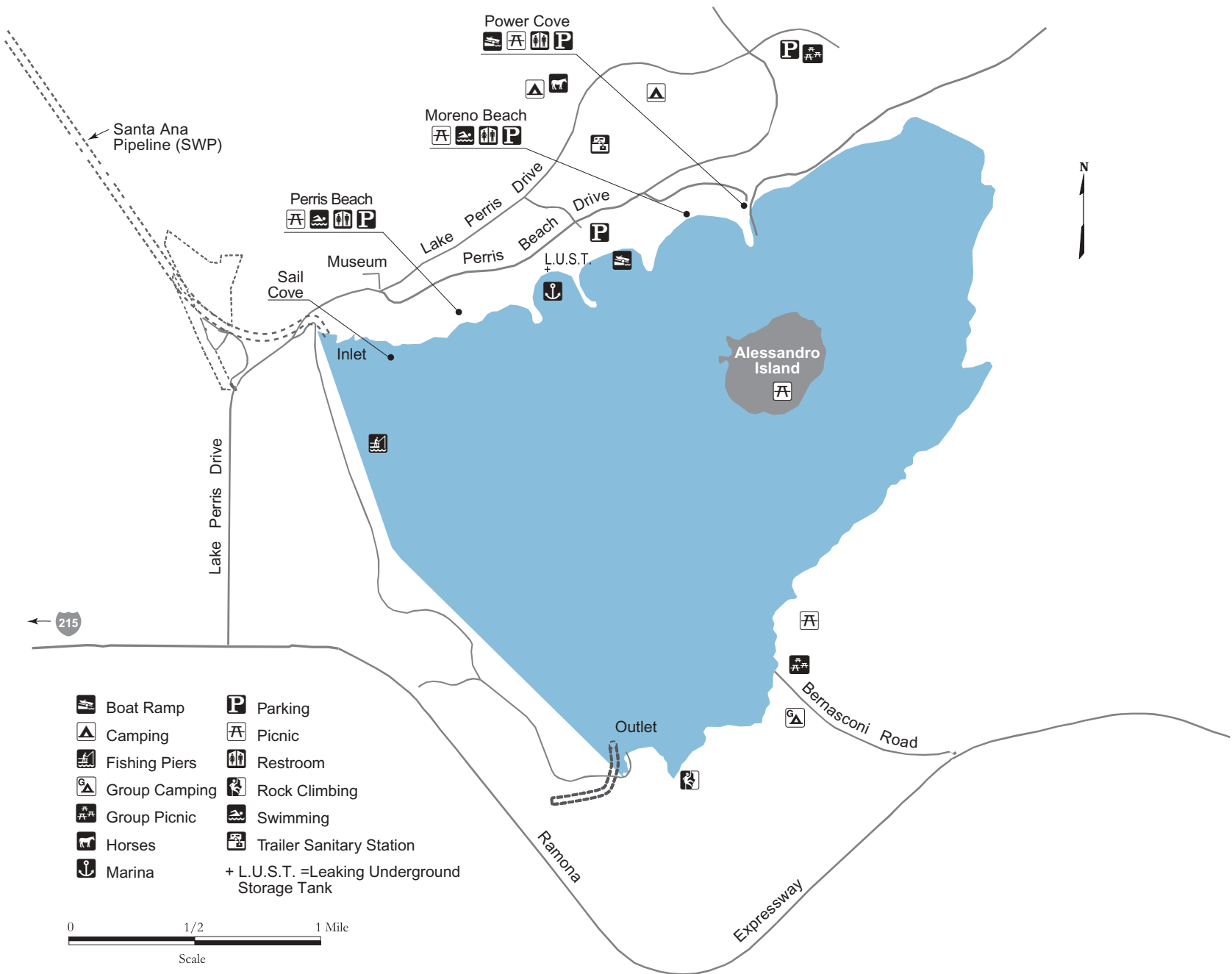
	1996	1997	1998	1999	2000
Jan	960	0	0	22	295
Feb	NA	0	0	0	204
Mar	NA	0	4,909	92	1,243
Apr	NA	21,032	18,120	0	5,117
May	2,018	3,714	7,498	13	1,821
Jun	754	357	12,769	<1.0	226
Jul	65	0	5,941	98	65
Aug	4,754	5,538	1,339	0	
Sep	NA	14,184	0	0	
Oct	0	0	1,463	519	
Nov	0	0	0	3,471	
Dec	0	0	0	80	
Total	8,550	44,825	52,039	4,295	8,971 ^a

Source: Torobin pers. comm. 2000

^a Deliveries only through July 2000.

NA – Not available.

Figure 7-23 Lake Perris



The majority of the recreational improvements are along the north shore of the lake and on Alessandro Island. The island has picnic grounds with water and chemical toilets. Along the lake's southern shore are facilities for rock climbing, picnicking, hunting, and camping. On the north shore are boat rentals, a marina with 300 boat slips, a store, a fuel dock, a boat repair shop, and dry storage. There are three 5-lane boat ramps, 2 swimming beaches, and a waterslide. On the north shore also are Sail Cove, for nonpower boating, and Power Cove, developed for personal watercraft use. The north shore provides day-use picnicking and overnight camping. There are approximately 430 campsites, 6 group campsites, and an equestrian camp that can sleep 56 people. There are about 64 chemical toilets, 33 permanent restrooms, and 3,100 parking spaces in the SRA.

Of the 4 Southern California SWP reservoirs, Lake Perris receives the heaviest recreational use with an average of 1,079,450 recreation days per year over the period 1996 to 1999 (Table 7-23). The number of boats allowed in the water varies with lake surface area. The boating capacity can range from 264 boats to 422 boats at full pool. Boating capacity at Lake Perris is controlled by the number of available parking spaces; however, during a 1998 MTBE study, MWDSC researchers counted 571 boats, either on the water or in the parking lots on Memorial Day (MWDSC 1998). Sixty percent of those boats were personal watercraft, and 17% were 2-stroke boats. A total of 101,810 boats visited Lake Perris during the 1996/1997 fiscal year (Stinson pers. comm. 1999).

Pathogens and MTBE are 2 of the main water quality concerns related to recreation at Lake Perris. Pathogen contamination is due to the high levels of body contact recreation, and MTBE contamination is the result of large numbers of motorized watercraft. The main source of MTBE in Lake Perris is recreational boating. There has been a history of bacteriological and pathogen contamination in the swimming areas on the north shore. Pathogens became an issue in the 1980s when outbreaks of illness were reported among swimmers. The 2 swimming beaches have been closed several times

since then because of high levels of total and fecal coliforms. Moreno Beach has been closed since 1997 because of high fecal coliform counts and has been converted to personal watercraft use (MWDSC 1998a).

California State Parks has taken steps to reduce the coliform counts and keep the beaches open. Since the 1980s, the department has implemented a sanitation education program and installed additional toilets on the beaches, approximately 50 feet from the shore. In 1991 it installed 2 circulation pumps at the beaches to increase circulation and move the pathogens away from the beaches. Originally, 1 pump was installed at each beach. The pumps were ineffective at lowering the pathogen concentrations in the swimming areas. In 1998, when Moreno beach was converted to personal watercraft use, both pumps were placed in operation at Perris Beach. Although the pumps may reduce the risk to swimmers, the DWR and the MWDSC are concerned that the pumps may increase the levels of pathogens at the outlet tower. No tracer or dye studies have been conducted to determine the amount of pathogens that will reach the outlet tower with and without the pumps.

Lake Perris has the highest overall MTBE concentrations of the 4 Southern California SWP reservoirs. MWDSC sampling has detected levels as high as 32 µg/L in Lake Perris. MTBE concentrations regularly exceed the MCL for MTBE in drinking water of 13 µg/L. A more detailed discussion is in Section 7.4.4, Water Quality Summary.

There have been several changes in recreational facilities since 1996. In 1999 concrete was replaced on boat ramps 5, 6, and 7. A new 4-lane personal watercraft launch ramp was constructed at Power Cove. Other new facilities include restrooms, a new parking lot for 55 cars and 63 trailers, 30 new picnic tables, and 700 feet of beach grading (DWR 1999). Construction of a new boat ramp to serve waterfowl hunters is planned for the Bernasconi area.

Table 7-23 Recreational Use at Lake Perris

Period	1996	1997	1998	1999
Recreation Days	1,157,300	1,101,000	1,007,400	1,052,100

Source: Thrapp pers. comm.

7.4.3.2 Wastewater Treatment/Facilities

Individual lift stations pump wastewater generated by the lake's recreational facilities to a main sump near the boat ramp area (Figure 7-23). From there, wastewater is lifted to a gravity line that flows to a treatment plant outside the watershed. The wastewater collection line that flows underneath the reservoir to Alessandro Island is no longer in use. The Lake Perris SRA contracts wastewater collection services from the Eastern Municipal Water District (EMWD). Operation and maintenance of the lift stations and lines is contracted to EMWD.

EMWD operates in compliance of the EPA's Capacity, Management, Operations, and Maintenance program. Requirements of this program include routine preventive maintenance and the development of an overflow response plan, which requires that EMWD take all feasible steps to mitigate any sewer system overflows. The overflow response plan also contains procedures for notification of the proper authorities in the event of an overflow, including the county health department and water suppliers.

There have been 2 wastewater overflow events since *Sanitary Survey Update 1996*. On 24 May 1998, the lift station that pumps wastewater from the restroom at Power Cove overtopped its sump, releasing approximately 50 gallons of wastewater that flowed about 50 feet over an area of sand toward the reservoir. The distance and the porous sand minimized the amount of sewage that entered the reservoir. County health officials were called to the scene, and water samples were collected from the reservoir. Approximately 900 feet of shoreline was disinfected using liquid chlorine. MWDSC stopped taking deliveries from Lake Perris pending results of the tests. The overflow occurred shortly after initial operation of the newly constructed lift station. Cause of the malfunction was determined to be a failed electrical switch.

The 2nd wastewater overflow occurred on 18 May 1999 at the Sail Cove lift station. EMWD workers were conducting routine maintenance when they ruptured a water line. An estimated 4,500 gallons of water flooded the adjacent lift station sump, which contained approximately 1,500 gallons of sewage. The mixture of fresh water and wastewater flowed toward the lake. The lift station is fewer than 100 feet from the lake. A storm drain immediately down grade of the lift station allowed the spill to reach the lake within minutes. Although total volume of the spill was relatively large (2,000 to 3,000 gallons), the wastewater was highly diluted by the fresh water. County health officials were called, and all wetted or pooled areas were disinfected. Samples were collected, and the area was closed to the public for several days.

There are 14 restrooms along the Lake Perris shoreline. All except those at Sail Cove and Power Cove are more than 300 feet from the reservoir. A trailer sanitary-station is a half mile north of the lake along Perris Drive. Wastewater spills from these facilities would have to flow a considerable distance over grass and sand to reach the lake. Alarms have been installed at Power Cove and Sail Cove to notify California State Parks and EMWD staff of wastewater overflows.

7.4.3.3 Urban Runoff

Runoff from parking lots associated with recreational facilities, other areas, and roads presumably drains to unpaved areas surrounding them and possibly eventually to the lake. No facilities exist for the collection of runoff from paved areas within the watershed (Agner pers. comm. 2000). However, there are no known water quality problems at Lake Perris caused by urban runoff.

7.4.3.4 Animal Populations

The watershed's animal population consists of wild animals and horses used for equestrian recreation. An equestrian campground north of the lake accommodates 56 people. An equestrian trail, which forms a loop around the lake, is in the upland areas of the watershed to avoid equestrian contact with the reservoir. However, MWDSC staff have observed equestrians riding across the peak of the dam. Apparently, inadequate fencing allows equestrians to access areas where horses are not allowed. This can result in increased soil erosion as well as introduction of pathogens from animal feces.

There is an abundant wild animal population at Lake Perris, including waterfowl. Large numbers of waterfowl using a reservoir can introduce a substantial amount of fecal material that can be a source of nutrients and pathogens. Terrestrial wildlife in the watershed can also be a source of pathogens.

7.4.3.5 Unauthorized Activity

Leaking Underground Storage Tanks

An underground storage tank at the Lake Perris marina failed in July of 1994. Approximately 50 feet from the shoreline and adjacent to the marina store, the underground tank released 5,000 to 6,000 gallons of gasoline with MTBE into the soil. Monitoring wells were installed, and free gasoline was detected floating on top of the groundwater. Gasoline was also observed floating on the surface of the lake, and a boom was installed to contain the contamination. A vapor extraction system was installed to remediate the soil contamination. The leaking underground tank was removed and replaced in February 1995.

Chemical contaminants observed as a result of the tank's failure include total volatile hydrocarbons and the gasoline components BTEX and MTBE. MTBE remains in high concentrations near where the tank leaked. The MTBE concentration in vapor extraction well number 1 was 180,000 µg/L on 22 September 1999. MTBE can be detected in monitoring wells as far as 100 feet north of the failed tank. At present, BTEX compounds can be detected in high concentrations near the area of the former leaking tank but not in monitoring wells farther away. Total petroleum hydrocarbons (TPH) concentration in vapor extraction well 1, which is adjacent to the leaking tank site, was 390,000 µg/L on 22 September 1999 (Boltinghouse pers. comm. 2000).

Because of the contamination site's proximity to the lake, its groundwater levels are directly related to the surface elevation of the lake. The high lake water surface elevation has hindered the vapor extraction remediation process over the last few years. Because the vapor extraction system is only effective at removing contaminants from dry soil, remediation efforts will only be successful when the lake is at low levels.

Approximately 4,686 gallons of gasoline have been recovered by the vapor extraction system as of March 1999. However, because of high groundwater levels in the remediation area, some product remains in the deeper soil (Boltinghouse pers. comm. 2000). Groundwater flow is to the north, away from the lakeshore. The lake was drawn down in the winter of 1997 for construction of a new personal watercraft ramp at Power Cove. The vapor extraction system functioned during the construction but was shut down in April 1998, when the lake was refilled. The vapor extraction system has been unable to function since April 1998 because of high lake levels.

7.4.3.6 Land Use Changes

The only land use changes that have occurred inside the watershed are related to changes in recreation facilities. These changes include the closure of Moreno Beach and construction of Power Cove for personal watercraft. Planned land use changes include the conversion of Moreno beach from a swimming facility to a personal watercraft

area or the reopening of Moreno Beach if California State Parks deems that the levels of pathogens at the beach can be controlled.

Land use changes outside of the watershed include substantial growth in residential development in the surrounding communities of western Riverside County. Several years ago, Riverside and San Bernardino counties ranked as the fastest growing counties in Southern California (Apante 1999). Although these developments are outside the watershed, they may have an indirect effect by increasing demand for recreation facilities and other indirect forms of contaminant introduction.

7.4.4 WATER QUALITY SUMMARY

7.4.4.1 Watershed

Water quality in Lake Perris presents a major concern to SWP contractors. There are several major water quality problems at Lake Perris. Each is discussed in this section. High levels of MTBE and concerns about pathogens limit the water utility use of the epilimnion during the summer stratified period. In addition, a condition known as hypolimnetic anoxia, which is a lack of oxygen in the lower reservoir or hypolimnion, further restricts the use of this part of the reservoir during this period. These restrictions on the use of Lake Perris have led to decreased water use, reducing the flow through the lake. This decreased flow has led to an increase in TDS levels, which further reduces the suitability of Lake Perris water for municipal and industrial uses. Water quality data are presented in Table 7-24. All parameters were below drinking water MCLs or applicable Article 19 objectives for this period.

Minor elements that were detected in at least 1 or more samples but at low levels included arsenic, barium, boron, chromium, copper, manganese, and zinc (Table 7-24). Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations by assuming the constituent was present at the detection limit; however, statistics were not calculated for parameters with 2 or fewer detections.

Table 7-24 Lake Perris Outlet, Feb 1996 to Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	Number of Detects/ Samples
Minerals							
Calcium	33	26	23	148	23-29	1	16/16
Chloride	89	89	65	121	67-116	1	16/16
Total Dissolved Solids	324	323	262	405	266-396	1	17/17
Hardness (as CaCO ₃)	129	132	111	148	113-147	1	16/16
Conductivity (µS/cm)	591	610	483	712	490-699	1	16/16
Magnesium	16	16	13	20	13-19	1	16/16
Sulfate	50	50	40	64	41-62	1	16/16
Turbidity (NTU)	1	1	<1	8	1-2	1	4/13
Minor Elements							
Arsenic	0.002	0.002	0.002	0.002	0.002-0.002	0.001	17/17
Barium	0.05	0.05	<0.05	0.06	<0.05-0.06	0.05	9/16
Boron	0.2	0.2	<0.2	0.3	<0.2-0.3	0.1	16/16
Chromium	0.005	0.005	<0.005	0.007	<0.005-0.006	0.005	3/16
Copper	0.008	0.005	<0.003	0.023	<0.003-0.019	0.002	12/16
Manganese	0.007	0.005	<0.005	0.027	<0.005-0.006	0.005	3/16
Zinc	0.011	<0.005	<0.005	0.009	<0.005-0.030	0.005	1/17
Nutrients							
Total Kjeldahl Nitrogen (as N)	0.5	0.4	0.3	1.2	0.4-0.6	0.1	27/27
Nitrate (as NO ₃)	0.2	0.1	<0.1	0.6	<0.1-0.3	0.1	5/16
Nitrate+Nitrite (as N)	0.03	0.01	<0.01	0.20	<0.01-0.08	0.01	23/47
Total Phosphorus	0.04	0.03	<0.01	0.15	<0.02-0.07	0.01	44/47
Orthophosphate	0.02	0.01	<0.01	0.05	<0.01-0.04	0.01	19/47
Misc.							
Bromide	0.21	0.21	0.20	0.22	0.20-0.22	0.01	3/3
pH (pH unit)	8.2	8.3	7.4	8.9	7.8-8.7	0.1	16/16

Source: DWR O&M Division database, May 2000

Notes: Bromide data from Feb 1999-Aug 1999 only

Statistics include values less than detection limit, if applicable

Hypolimnetic Anoxia

Because of high nitrogen and phosphorus loading from the SWP, direct runoff and precipitation, Lake Perris is nutrient-rich and would be classified as eutrophic with respect to algal productivity. Nutrient levels indirectly affect water quality in these lakes by stimulating growth of nuisance algae that are associated with release of taste and odor compounds such as geosmin and MIB. High concentrations of certain diatom species can also affect treatment plant operations by clogging filters and interfering with coagulation and flocculation. Eutrophic lakes often experience periods of anoxia in bottom waters because of microbial respiration fueled by periodic die-off of algae. Anaerobic water contains elevated concentrations of reduced compounds that require higher doses of oxidants during the treatment process. These reduced compounds are also odorous and bad tasting (for example, hydrogen sulfide), and decrease the aesthetic quality of the water. Metals such as iron, manganese, and certain nutrients are more soluble in anoxic waters owing to low pH.

During spring, Lake Perris typically has low turbidity, good light penetration and no temperature stratification (Coburn pers. comm. 2001; Losee pers. comm. 2001). As spring progresses, water temperatures rise and stimulate algal growth resulting in an algal bloom. Decreasing water clarity caused by the bloom coupled with increasing solar inputs (longer days, higher sun angle) results in thermal stratification of the lake. The warmer (less dense) upper portion of the water column is separated by a thermocline (region of maximum temperature change with depth) from the colder (more dense) lower portion of the water column. The upper portion of the lake is referred to as the epilimnion and is typically well mixed, and light levels are sufficient for algae to grow, thus oxygen levels are high. The portion of the lake below the thermocline is referred to as the hypolimnion and is usually too dark for algal growth. Microbial respiration (consumption of oxygen) fueled by organic materials (dead algae) that sink from the epilimnion and by algal respiration

(sinking live-algae) can lead to low oxygen levels (hypoxia) or a total depletion of dissolved oxygen (anoxia) in the hypolimnion.

By mid to late summer, nutrients have been depleted by algal growth in the epilimnion, and algal biomass declines (nutrients released by microbial decomposition in the hypolimnion cannot be resupplied to the epilimnion while a strong thermocline persists). Thermal stratification typically persists into the fall when surface water cools and becomes more dense (it sinks) resulting in a lake mixing or turnover event. Wind can also contribute to lake mixing. When the lake mixes, turbidity decreases and nutrients that have accumulated in hypolimnetic waters reach depths in the lakes with sufficient light for algal growth, leading to a fall bloom.

Anoxic conditions in Lake Perris lead to approximately 30% to 40% of the lake's total volume being unusable for drinking water during the summer stratified period (MWDSC 1998a). This period also represents the period of highest water demand. Since operation of the MWDSC hydro-generation plant, algal productivity has decreased because of lower SWP inputs (there is less nutrient loading to the lake). This decrease in nutrient load has shifted the onset of hypolimnetic anoxia from late May to late August or early September.

MTBE

In 1997 DWR staff collected samples for MTBE analysis at 3 depths at the outlet tower. Depth 1 (D1, etc.) was the surface. Depth 2 was the lower limit of the epilimnion, which varied in depth throughout the season. The deep water samples, depth 3, were collected below the thermocline in the hypolimnion. Results are presented in Table 7-25 and Figure 7-24. MTBE levels in Lake Perris were higher than other reservoirs with less recreation. Summer MTBE concentrations reached levels as high as 32 µg/L near the boat ramp and 11 µg/L at the outlet tower, both exceeding the primary MCL of 13 µg/L (DWR 1999a).

Table 7-25 Summary of MTBE Concentrations in Lake Perris (µg/L)

MWDSC Sampling	Outlet (1997)		Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion)				
Range	3.9 - 25	ND - 5.0	16 - 45	1.6 - 7.7
Mean	14	2.0	25	5.2
Bottom (Hypolimnion)				
Range	ND - 8.0	N/S	N/S	N/S
Mean	3.7	N/S	N/S	N/S
DWR Sampling	Outlet (1997/1998)		Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion D1 +D2)				
Range	1.0- 25	N/S	12 - 32	N/S
Mean	11	N/S	22	N/S
Bottom (Hypolimnion)				
Range	ND - 18	N/S	N/S	N/S
Mean	5.5	N/S	N/S	N/S

Note: Surface samples include samples collected from 0.5 to 10 meters

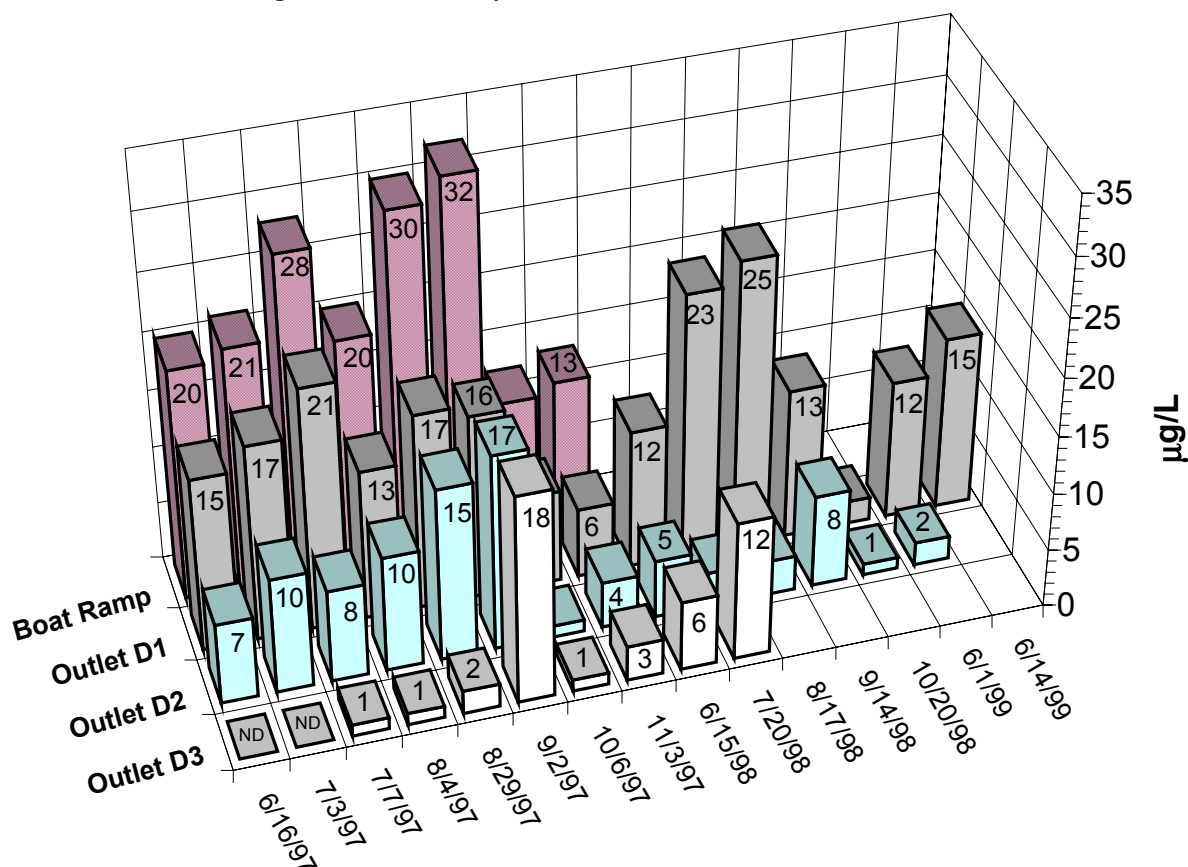
ND = Not Detected.

N/S = Not Sampled

Thermal stratification during summer recreation season leads to a build-up of MTBE in the upper layers of the lake. Surface samples at the outlet tower ranged from 1 to 25 µg/L with a mean of 11 µg/L. MTBE concentrations at depth 2 ranged from

1 to 17 µg/L, with a mean of 8.9 µg/L. The high value was observed in late August, and the low value was observed in October. MTBE in the hypolimnion (D3) ranged from 1 to 3 µg/L, except on September 2, when a concentration of 18 µg/L was observed.

Figure 7-24 Summary of MTBE Concentrations in Lake Perris



Data sources: DWR 1999, DWR Division of Operations and Maintenance unpublished data 1998

MWDSC also collected samples in Lake Perris during the 1997 recreation season (Table 7-25). MTBE concentrations in surface samples collected during the summer at the outlet tower ranged from 3.9 to 25 µg/L with a mean of 13.5 µg/L. Samples collected in the hypolimnion during the summer months ranged from nondetect to 8 µg/L, with a mean of 3.7 µg/L.

When thermal stratification breaks down in fall, the lake mixes and MTBE spreads throughout the water column. Along with volatilization, this leads to decreasing MTBE concentrations. Lake Perris was thermally stratified from late June until early October in 1997. During winter 1997/1998, MTBE concentrations declined to ambient levels throughout the water column. Surface samples collected at the outlet tower had a mean of 2.0 µg/L, while samples collected at the boat ramp had a mean of 5.2 µg/L. Three factors had a role in this decline. Decreased recreational boating led to lower MTBE loading, and the thermocline began to weaken in October. This caused the lake to mix, and MTBE was dispersed

throughout the water column. Volatilization also eliminated some MTBE from the reservoir.

MTBE concentrations were higher near the boat ramp than at the outlet tower. DWR sampling in 1997 showed MTBE concentrations ranging from 12 to 32 µg/L in surface samples collected at the boat ramp, with a mean of 22 µg/L (Table 7-25). MWDSC sampling showed values at the boat ramp ranging from 16 to 45 µg/L in the summer. The mean was 24.6 µg/L. During winter months, the range was 1.6 to 7.7 µg/L with a mean of 5.2 µg/L.

MTBE concentrations increased over holiday weekends. Samples were collected before and after 4th of July and Labor Day weekends 1997. These weekends represent the periods of highest recreational use in the lake. Over the 4th of July weekend, MTBE concentrations increased by 4 µg/L at the outlet tower and 7 µg/L at the boat ramp. The changes were not as dramatic over Labor Day weekend. Concentrations rose 2 µg/L at the boat ramp but declined by 1 µg/L at the outlet tower.

Lake Perris has the highest recreational use of the 4 SWP Southern California reservoirs and thus has

much higher MTBE concentrations. MTBE concentrates in the upper layer of the lake during the summer months. Samples taken in 1997 showed values exceeding the DHS primary MCL of 13 µg/L. Samples collected near the boat ramp had MTBE concentrations nearly twice the primary MCL. Samples collected during winter were generally at or below the secondary MCL of 5 µg/L.

Total Dissolved Solids

Because of water quality problems associated with anoxia in the hypolimnion, MTBE, and pathogens, much of Lake Perris is unusable for water utilities much of the year. The period when the water quality is at its worst is in summer and early fall, which are periods of highest water demand. This situation has led contractors to decrease their use of Perris water. With reduced or no deliveries from Lake Perris, the flow through the lake has decreased. Evaporation causes loss of water from the lake without the loss of the accompanying dissolved solids, and with low inflow to the lake, TDS concentrations have increased.

TDS levels from 1996 to 1999 ranged from 262 to 405 mg/L with a mean of 324 mg/L (Table 7-24). These concentrations were below the secondary MCL of 500 mg/L but routinely exceeded the 10-year average Article 19 objective of 220 mg/L. Water flows into Lake Perris from Silverwood Lake through the Santa Ana Pipeline. TDS levels in Lake Perris are significantly higher than those observed in Silverwood Lake. Silverwood TDS readings ranged from 148 to 246 mg/L with a mean of 198 mg/L. This increase illustrates the effect of evaporation on TDS levels in Lake Perris.

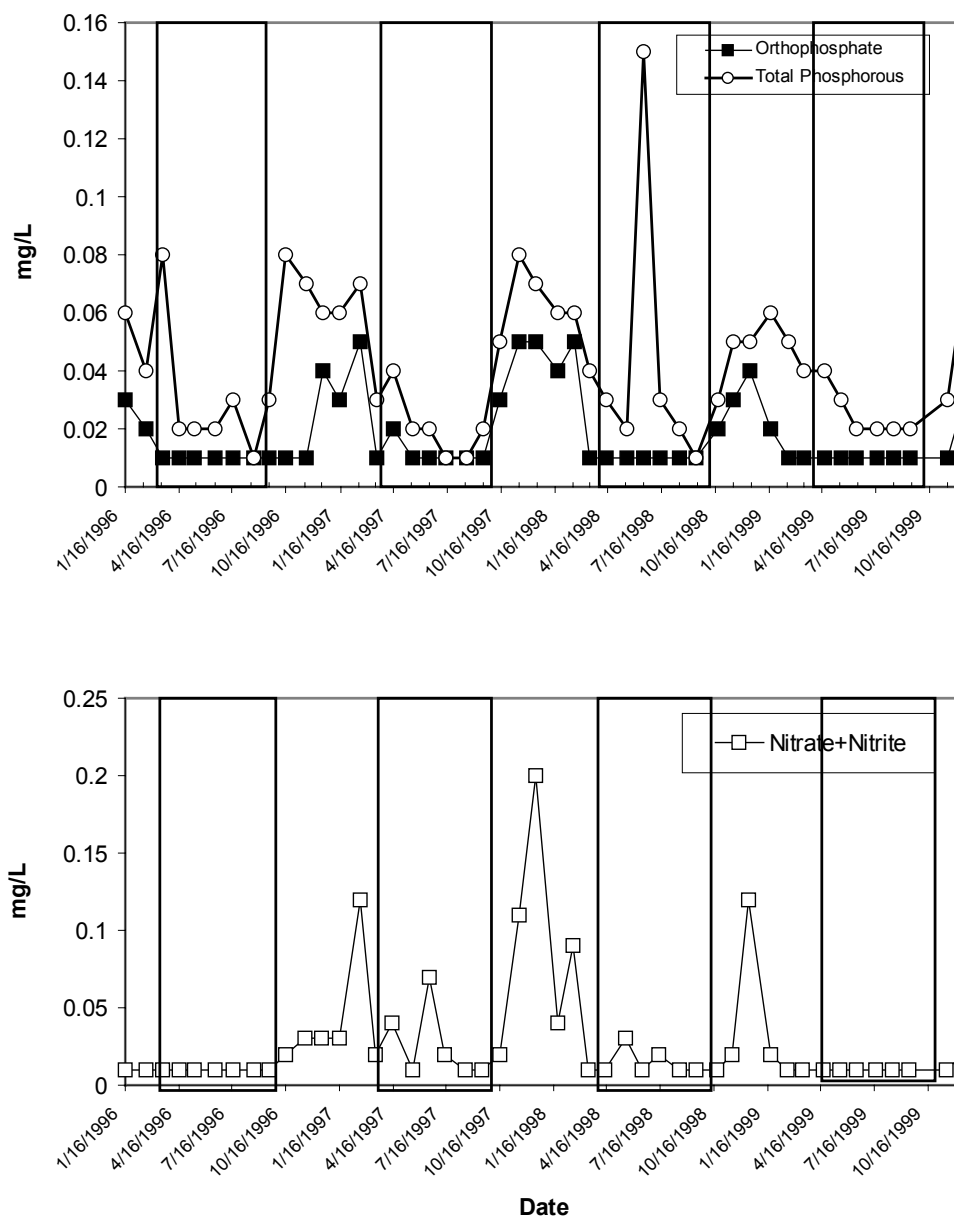
The effects of evapoconcentration is also observed for several other water quality parameters. Sulfate, chloride, bromide and hardness were all observed at higher levels in Lake Perris than in Silverwood Lake (see Tables 7-24 and 7-17). Sulfate concentrations were roughly twice as high in Lake Perris as they were in Silverwood Lake. However, all sulfate values were below the secondary MCL of 250 mg/L.

Chloride concentrations also doubled in Lake Perris compared to Silverwood Lake. Chloride concentrations were well below the secondary MCL of 250 mg/L. Hardness and bromide followed similar patterns. Quarterly sampling for bromide began in 1999. Bromide was detected in all samples collected that year with a mean of 0.21 mg/L. Bromide is oxidized to bromate during the treatment process. Bromate is considered a human carcinogen by the California Office of Environmental Health Hazard Assessment and has an MCL of 0.01 mg/L. In order to meet this standard for bromate in finished water, the SWP contractors have identified a goal of 0.05 mg/L for bromide in raw water. Bromide levels in Lake Perris were approximately 4 times higher than this objective.

Nutrients

Nitrogen levels in Lake Perris were generally lower than Castaic or Silverwood lakes, while phosphorus was about the same as Castaic and somewhat lower than Silverwood. However, the same seasonal pattern of summer increase and winter decrease was observed (Figure 7-25). Total phosphorus levels in Lake Perris ranged from <0.01 mg/L to 0.15 mg/L, averaging 0.04 mg/L. Orthophosphate levels ranged from <0.01 mg/L to 0.05 mg/L, averaging 0.02 mg/L (Table 7-24). The high value of 0.15 mg/L total phosphorus occurred in July 1998 and could be an outlier because the sample for orthophosphate on the same date was <0.01 mg/L, although laboratory quality controls were all within acceptable ranges (Fong pers. comm. 2000).

Nitrogen followed the same seasonal pattern as phosphorus (Figure 7-25). Kjeldahl nitrogen (as N) in Lake Perris ranged from 0.3 to 1.2 mg/L, averaging 0.5 mg/L. Nitrate and nitrite (as N) ranged from <0.01 mg/L to 0.2 mg/L and averaged 0.03 mg/L. The high nitrate value was in February 1998 during the El Niño storm period and remained below this level throughout the year.

Figure 7-25 Nutrient Concentrations in Lake Perris, 1996 to 1999

Data source: DWR O&M Division database, May 2000

Boxed areas represent approximate algal growing season, May through October.

Taste and Odor

Algal blooms lead to increased levels of the compounds 2-methylisoborneol (MIB) and geosmin, which cause taste and odor and contribute to negative aesthetic qualities. These 2 compounds are not readily removed by the treatment process and present

additional problems for utilities treating raw water. They are also commonly associated with blooms of blue-green algae in reservoirs.

MIB and geosmin levels were higher at Lake Perris than at other SWP reservoirs (Table 7-26). The highest values were observed at the lake inlet and at the lake center. Geosmin at the inlet ranged

from ND to 179 ng/L with a mean of 9.2 ng/L. The inlet is on the north side of the lake, near Sail Cove. On the other side of the reservoir, at the outlet structure, geosmin ranged from ND to 87 ng/L with a mean of 7.1 ng/L.

MIB and geosmin levels were higher in summer and fall months (Figure 7-26). However, this pattern was not as strong at Perris as it was at other SWP reservoirs. Levels at or near the taste and odor detection threshold (5 to 10 ng/L) were observed between April and November of most years. The lowest values were also observed between January and March of most years. There were several peaks in MIB and geosmin concentrations observed in January, May and October 1997 and early June 1999 that greatly exceeded the taste and odor detection threshold. In summer 1997, a blue-green algal bloom required application of 10 tons of copper sulfate by DWR (MWDSC 1997).

MIB and geosmin concentrations were higher at the surface and declined with increasing depth (Fig.

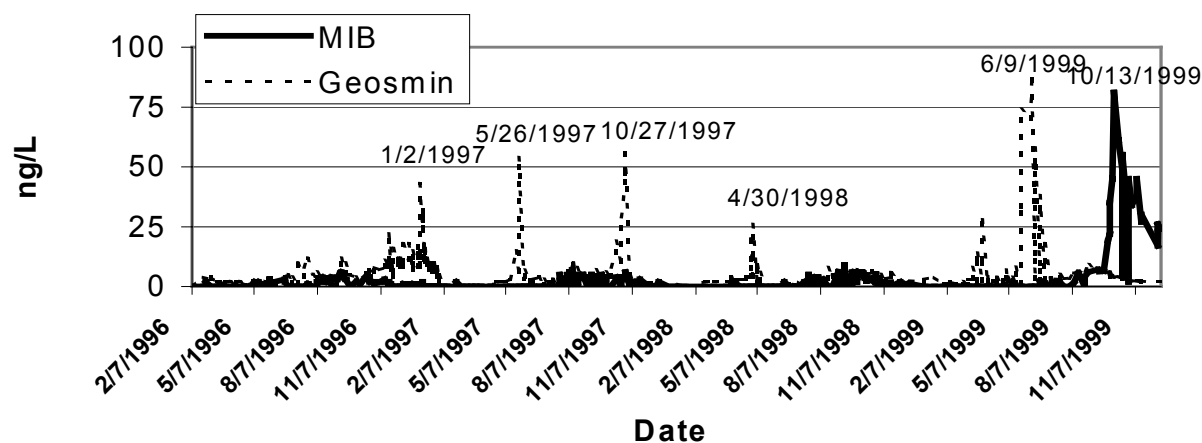
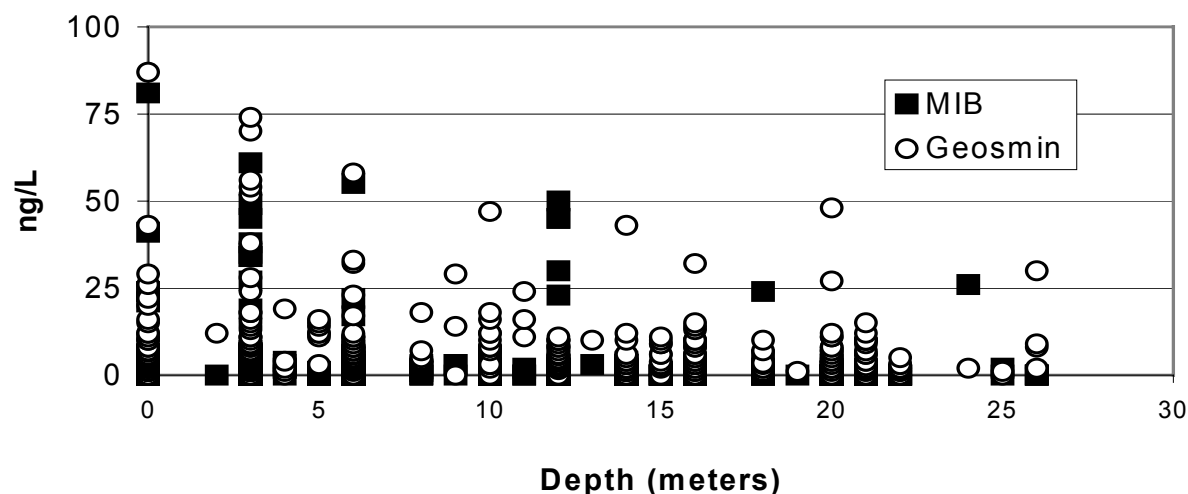
7-26 bottom). MIB in the upper portion of the epilimnion (0 to 5 meters) ranged from ND to 81 ng/L at the outlet tower. When detected the mean was 8.4 ng/L. MIB at the bottom of the outlet tower (> 20 meters) ranged from ND to 26 ng/L with a mean of 4.8 ng/L. Surface concentrations of geosmin at the outlet tower ranged from ND to 87 ng/L. When detected, the mean was 7.6 ng/L. Geosmin concentrations at the bottom of the outlet tower ranged from ND to 48 ng/L. The mean of all samples with detectable concentrations was 6.5 ng/L.

The lowest MIB and geosmin concentrations were observed in the lake outflow. Geosmin concentrations in the outflow ranged from below the detection limit to 5 ng/L. When detected, the mean was 2.8 ng/L (Table 7-26). Only 1 sample collected from the lake outflow contained MIB at levels above the taste and odor threshold. Lower concentrations observed in lake outflow may be a result of reservoir management practices such as selective depth and/or timed withdrawal.

Table 7-26 MIB and Geosmin Concentrations in Lake Perris, 1996 to 1999 (ng/L)

	MIB	Geosmin
Lake Inlet		
Range	ND to 59	ND to 160
Mean	7.8	8.0
Percent of Samples with Detectable levels	52%	84%
Lake Center		
Range	ND to 51	ND to 179
Mean	8.0	9.2
Percent of Samples with Detectable levels	38%	86%
Lake Outlet		
Range	ND to 81	ND to 87
Mean	7.0	7.1
Percent of Samples with Detectable levels	37%	82%
Lake Effluent		
Range	ND to 37	ND to 5.0
Mean	8.0	2.8
Percent of Samples with Detectable levels	38%	75%

Note: Mean values do not include samples where no analyte was detected
ND = Not Detected

Figure 7-26 MIB and Geosmin Levels at the Lake Perris Outlet, 1996 to 1999**MIB and Geosmin Levels by Depth - Lake Perris Outlet**

7.4.4.2 Water Supply System

Water quality of utilities using Lake Perris water was not investigated because of the limited use as SWP supply. Additionally, water from Lake Perris used by MWDSC is mixed with Colorado River water, typically at less than 25%. Therefore, treatment plant data would not accurately reflect Lake Perris effluent water quality.

7.4.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

High levels of recreation have a significant effect on water quality at Lake Perris. High concentrations of MTBE from motorized boating and concerns about

pathogen loading from body-contact recreation combine to restrict the use of upper layer water during the period of highest water demand. Water utilities have expressed concern that bathers in the swimming area during periods of high recreation could contribute to high pathogen levels that in turn could potentially overwhelm the treatment process. Additionally, pathogen concentrations present a significant risk to the recreationists themselves, as evidenced by frequent beach closures.

Anoxic conditions in the lower lake layer also limit the use of this water during the period of highest water demand. Anoxia is a naturally occurring condition that leads to high concentrations of reduced

compounds and odorous chemicals. These reduced compounds require extra doses of oxidants, increasing treatment costs.

The water quality concerns in Lake Perris have led to decreased use of water from the lake. This leads to decreased flow through the lake. Decreasing flow through the lake increases the concentration of dissolved solids. High dissolved solids concentrations further contribute to the unsuitability of Lake Perris water for the contractor's use.

The leaking underground storage tank that was removed from the marina in 1994 continues to contaminate groundwater adjacent to the lake. High water levels in the lake have hampered the remediation process.

7.4.6 WATERSHED MANAGEMENT PRACTICES

There are several agencies with management authority in the Lake Perris watershed. DWR constructed the reservoir and is primarily responsible for its operation. California State Parks manages the Lake Perris SRA, controlling the types of recreation within the watershed. DBW regulates recreational boating. The MWDSC is the only contractor in this reach of the SWP and is involved with DWR in reservoir management decisions such as controlling lake outflow.

As with the other reservoirs, recreation presents the largest watershed management issue at Lake Perris. Recreational activities often present significant sources of contamination, and these activities often can be significant sources of contamination. Strategies to address and mitigate this impact are being discussed in a water quality/recreation focus group of staff representing: DWR, California State Parks, and other involved agencies. Among specific actions taken at Lake Perris is the installation of pumps near the beach areas to increase circulation away from the beaches. These pumps are designed to move the pathogens farther from the recreationists to reduce their risk; however, the practice has the potential to spread the pathogen contamination throughout the lake, possibly increasing the pathogen concentration at the lake outlet. Limits on the numbers of watercraft allowed on the lake may help control MTBE contamination, but these limits appear to be dictated more by safety for the boaters and less by water quality concerns.

The EMWD is responsible for the maintenance and operation of the wastewater collection activities in the watershed and upgraded wastewater collection facilities to reduce the risk of future sewage leaks. These upgrades include 24-hour monitoring at several lift stations. The California Department of Fish and Game is responsible for managing the

wildlife habitat in the watershed. All of these entities work toward the common goal of providing recreation and wildlife habitat as well as maintaining drinking water quality.

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